NASA TECHNICAL TRANSLATION NASA TT- 20365

CURRENT ACHIEVEMENTS IN COSMONAUTICS

P. 62

Translation from the Russian of "Sovremennyye dostizheniya kosmonavtiki". Novoye v Zhizni, Nauke, Tekhnike: Seriya "Kosmonavtika, Astronomiya", Broshuyry Izdatel'stvo "Znaniye", No. 12, 1987, pp 1-64.

(NASA-TT-20365) CURRENT ACHIEVEMENTS IN COSMONAUTICS (NASA) 62 p CSCL 22A

N89-14245

Unclas

G5/12 0172890

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C. NOVEMBER 1988

NASA
National Aeronautics and Space Administration

Report Documentation Page

1. Report No. NASA TT 20365	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle CURRENT ACHIEVEMENTS IN COSMONAUTICS		5. Report Date NOVEMBER 1988
		6. Performing Organization Code
7. Author(s) L.A. Yerlykin, Editor		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address National Aeronautics and Space Administration Washington, DC 20546		11. Contract or Grant No. NASW-4307
		13. Type of Report and Period Covered translation
12. Sponsoring Agency Name and Address NATIONAL AERONAUTICS AND SPACE ADMINISTRATION WASHINGTON, DC 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Tranlation from the Russian of "Sovremennyye dostizheniya kostizheniya kosmonavtiki". Novoye v Zhizni, Nauke, Tekhnike: Seriya "Kosmonavtika, Astronomiya", Brosyuyry Izdatel'stvo "Znaniye", No. 12, 1987, pp 1-64.

16. Abstract

The articles presented in this collection of works tell of the latest achievements in Soviet cosmonautics: the regular expedition of cosmonauts to the "Mir" orbital station, and the successful development of USSR international cooperation in the sphere of cosmonautics. Information is also presented on the start of operation of the new Japanese booster rocket.

17. Key Words (Suggested by Author(s))	18. Distribution Statement THIS COPYRIGHTED SOVIET WORK IS REPRODUCED AND SOLD BY NTIS UNDER LICENSE FROM VAAP, THE SOVIET COPYRIGHT AGENCY. NO FURTHER COPYING IS PERMITTED WITHOUT PERMISSION FROM VAAP.

19. Security Classif. (of this report) unclassified	20. Security Classif. (of this page) unclassified	21. No. of pages 60	22. Price

NASA FORM 1626 OCT 86

"Current Achievements in Cosmonautics: Collection of Articles". Moscow. Znaniye, 1987. 64 p. (Novoye v zhizni, nauke, tekhnike. (What's New in Life, Science, Technology. Series "Cosmonautics, Astronomy". No. 12). Price: 11 kopeks.

The articles presented in this collection of works tell of the latest achievements in Soviet cosmonautics: the regular expedition of cosmonauts to the "Mir" orbital station, and the successful development of USSR international cooperation in the sphere of cosmonautics. Information is also presented on the start of exploitation of the new Japanese booster rocket.

This brochure is intended for a broad readership and those interested in current cosmonautics.

"MIR": THE SECOND MAIN EXPEDITION (CHRONICLE OF THE FLIGHT)

V. P. Savinykh*

It has become customary in our country that the program of a manned flight begins with the launch of an unmanned craft. This is how it was in this case. First the automatic cargo ship "Progress-27" was launched from Earth into orbit. And exactly 3 weeks later, on 6 February 1987, the "Soyuz TM-2" was launched--the first craft of this series with a crew on board. Although one such craft had already performed a run to the "Mir" station in May of last year, this was only a "dry run" in the unmanned version. And so the cosmonauts set off for space in the new craft. /3**

It was the regularly scheduled space crew. There were two of them. One of them is well known. It consisted of two-time Hero of the Soviet Union, USSR pilot-cosmonaut Yuriy Romanenko. The other was Aleksandr Laveykin--a newcomer.

Once during the conversation of the crew with journalists before their departure for the cosmodrome, the deputy chief of the Center for Cosmonaut Training imeni Yu. A. Gagarin, A. A. Leonov, asked Aleksandr Laveykin: "Sasha, you were lucky to get this commander, weren't you?" "Of course, undoubtedly," the latter answered without stopping to think. "Yura is an experienced man. It is easy to work with him on Earth. I believe it will be the same in space". Aleksey Arkhipovich smiled coyly and turned to Yuriy Romanenko: "Yura, why is your call name 'Raymir'?" Yuriy Romanenko paused a bit, but answered: "'Taymir' is supposed to be a symbol of far-off travels. At that time Sasha Ivanchenkov and I were preparing for flight. We shared the common desire to change places, the desire for tourism. And so Major-General Leonov once gave me a strict reprimand for one such trip... Yet I had never yet been to Taymir".

Aleksandr Laveykin is also no stranger to this passion. Moreover, he plays the guitar well and knows many songs written by amateur songwriters. And these songs are faithful fellow companions in our worldly travels. Many of them

---

* Candidate in technical sciences, USSR pilot-cosmonaut.

** Numbers in margins indicate foreign pagination.

originated during geological expeditions or around a campfire. Yuriy Romanenko is a great fan of such songs, so he and Aleksandr are in tune both in a literal /4 and in a figurative sense. Therefore we were sure that their joint space watch would strengthen their duet even more.

Two people in one spacecraft, on one orbital station--that is already a full-fledged scientific experiment for medical men and psychologists. During crew selection on Earth must attention is given to the spiritual compatibility of its members. Sometimes the optimal result is achieved not only by a similarity of characters, but also by their difference. The crew is united by a common goal...

It is still 2½ hours to launch, but the crew is already in the spacecraft, which is mounted on the booster rocket. Here everything is the same as on the trainer, and yet there are some differences: there is less free space, since the craft is fully loaded, and there are different sensations. The automatism of movements has been retained, but now the cosmonauts control themselves more strictly, check all the ship's systems synchronously with Earth control, check their space suits, and coordinate parameters according to the readings of their instruments and the telemetric data from Earth. I remember when I was sitting in the "Soyuz T-4", that for a moment I got the alarming thought that they might cancel the launch. It was then that I felt most acutely how much I wanted to fly in space.

The checks continued. Finally it became clear that everything was in order and all systems were operating normally. The cosmonauts lowered their helmet visors. The last minutes of their presence on Earth were elapsing, and soon the command "Key to launch!" would resound. This key by tradition is given to the cosmonaut to keep after the flight. It is the launch key, cast by the golden hands of our workers. The command "Key to launch!" contains the emotional content of this entire moment, plus all your preceding life. It signifies the progressive movement of our country and Soviet science, and the inspirational force of the Communist Party, whose membership is felt with particular force during these minutes.

"What do you feel during the moment of launch? What is your emotional state on this emotional day?" In asking these questions which have already become traditional, journalists and even the interested public expect to hear something that will startle the imagination. When they don't hear it, they try to hide their disappointment, but, I believe, cling to the secret conviction that the cosmonaut really does experience some unusual feelings. It is simply that the human tongue is unable to express the entire depth of the "cosmic" experiences. /5

In preparing for flight, one really does experience great excitement. But imagine that you are going in to take an important exam. If you have prepared well for it, then the worry is necessarily replaced by a calm assurance of your own powers, an elevated mood, the desire to show what you are capable of. That is how it was with us. In setting off for flight, we must be confident of the fact that all the ship's systems will operate normally. The spacecraft and the cosmonaut are an integral unit in flight, and we must know the systems of our space house like we know our own five fingers. Of course, the automatic systems will take over if necessary, but the cosmonaut is the master of these automatics and must always be ready. As for the emotional background, it is not removed, but fades into the background--with action remaining in the forefront. Quick-wittedness, concentration, cheerfulness--these are necessary conditions for any crucial work.

Launch! The rocket smoothly lifts off from the launch pad. "Flight is normal... Parameters are within the norm... We have separation of the first stage..."--the reports follow continuously over the entire time of placement of the spacecraft into orbit. At an altitude of around 80 km the nosecone is thrown off. The portholes of the craft are open, but the crew still cannot see the Earth. The second stage has separated, and third is operating... And then there is weightlessness. It is a strange sensation. You are sitting in a chair, but it seems like you are hanging over the control panel. There seems to be a shift in the system of coordinates in your perception.

During the first orbit the air-tightness of the spacecraft is checked. As for the reaction to weightlessness--the swelling of the face, the lumps in your throat--all this has to be endured in working order. The crew knows that the comrades at the Flight Control Center, the FCC, are awake and alert. And that is how it will be for the duration of their entire stay in space. And they can sleep soundly in orbit because you have endless faith in those who are now hunched over the control panels at the FCC. The comrades are always on the alert, every moment keeping an eye on both the crew and the spacecraft. They are always together with those who are in orbit.

The two-day scheme of approach of the spacecraft to the station is not only more expedient in an energetic sense, but also more convenient for the crew. When I launched for the first time, at that time the docking was performed after 24 hours. That is why Vladimir Kovalenko and I slept the first night in space not in the living quarters, but in the descent apparatus, in our chairs. There was no sense in getting comfortable, since we had only the necessary minimum of time left for rest. In the morning we immediately began performing approach maneuvers. /6

Docking is one of the most crucial moments of the flight. If it occurs successfully, the "Taymirs" will go on board the "Mir"-"Progress-27" complex and will continue the program of research begun by Leonid Kizim and Vladimir Solov'yev. Otherwise, they will have to return to Earth, and a new stage in the operation of the "Mir" station would have to be put off until the next launch. During this key moment of the flight, the FCC is watchful, working, and taking all the necessary measures to ensure the successful performance of the docking operations.

The ship confidently approaches the station. The automatic instrumentation, as they say in such cases, works like clockwork. However, perhaps in the epoch of space flights it is time to place this comparison in the archives. It has become outdated and reflects the inertia of our earthly thought. In actuality, the automatic instrumentation works so precisely that often this precision has no comparison. It is flawless precision bordering on the fantastic.

The manned space complex "Mir"--"Soyuz TM-2"--"Progress-27" is in orbit... In the official reports it is called by only two words--the "Mir" complex. In my opinion, this is more correct. After all, in the future the complex may consist, aside from the base unit, also of five other modules and two ships. Just try to name all of them each time.

On the station, under conditions of its considerably greater volume (as compared with the volume inside the ship) weightlessness is felt more acutely, and it is necessary to take the necessary precautionary measures so that adaptation will occur without any unpleasant occurrences. This concerns primarily the newcomers, since people who have already been in space become re-accustomed to weightlessness much more easily. All the operations must be performed slowly. If you turn, you have to do so with your entire body, and not just turn the head. The FCC always carefully oversees the newcomers, constantly reminding them of this. And there, in their space house, his commander and friend, Yuriy Romanenko, helps Aleksandr Laveykin to become more quickly accustomed to weightlessness. /7

It is also not easy to fly in weightlessness. You do not immediately realize that if you are floating in some direction, it is useless to jerk around. You have to float over to any plane, and then push off from it in the necessary direction and float over to your target. Weightlessness continues to conceal many riddles. Its effect on the human organism, especially in the acute period of adaptation to weightlessness, is a source of great interest to medical men. Unfortunately, however, when the crew of the main expedition is on the station, it does not have time for medicine. In the first days there is very much work to be done. The on-board systems must be taken out of storage mode, the station has to be changed over to a regimen of manned flight, and only then can scientific experiments be undertaken. Of course, by that time the acute period of adaptation has been completed, and the medical men have to satisfy themselves with recording its results. However, when a visiting expedition comes to an inhabited station, here they can not pass up the opportunity to pursue their goals.

The first comprehensive medical examination of the "Taymirs" was performed on 16 February, i.e., 10 days after the launch. It included a study of the cardiovascular system, a measurement of the body mass, an evaluation of the state of the muscles, which are insufficiently loaded in weightlessness. Medical control over the health of the cosmonauts is constantly being implemented, but periodically more detailed comprehensive examinations are conducted so as to predict the work capacity of the crew and to correct the program of physical exercises.

At the end of February Yuriy Romanenko and Aleksandr Laveykin began their geophysical research. With the aid of spectrometers, a stationary KATE-140 photo camera and hand-held cameras they photographed certain sections of the USSR territory in the middle and southern latitudes, as well as the aquatoria of the World Ocean. One of the first stages in the scientific program of the "Taymirs" was also the series of experiments on space materials science on the "Pion-M" installation.

As we know, on Earth a convective heat exchange occurs due to the different specific weight of layers of liquid or gas heated to different temperatures.

This brings us to a logical conclusion: In the absence of gravity there also /8
should be no convection. And life in orbit seems to confirm this. Due to the absence of convection there are stagnant zones formed in the compartments of the spacecraft and the orbital stations, while the air heated by the body quickly wraps the cosmonaut in a stuffy blanket. Therefore, ventilators must operate both day and night, moving the air flows throughout the station and thereby mixing the atmosphere in the living compartments.

When Vladimir Dzhanibekov and I were restoring the lifeless "Salyut-7" station, it was not recommended that we both be in the work compartment at the same time until the ventilators were turned on. After all, each of us could breathe such a cloud of carbon dioxide around him that it would be impossible to breathe. Yet it is impossible to sit in different compartments all the time. So as not to make Earth nervous needlessly, we told them that we had separated, when in fact, of course, we worked together, each chasing away the cloud around himself with makeshift methods.

Thus, convection in weightlessness, at least in the sensations customary to us, does not manifest itself. Thus, theoreticians and practical specialists agreed on the fact that there is no convection in weightlessness. However, the first experiments on space materials science introduced corrections into this seeming rudimentary truth. Scientists nevertheless encountered convection, although it was manifested differently in weightlessness. The reason for convection in this case are the themocapillary forces. Naturally, they are present also in earth conditions, although as compared with the gravitational forces they are so insignificant that they have practically no effect on the processes of fusion and crystallization of materials. In weightlessness, however, thermocapillary convection is rather active in the absence of any competition, and worsens the properties of the obtained materials.

In the electrical heating devices of the type "Splav" (Alloy), "Kristall" (Crystal), and "Korund" (Corundum), the processes are "concealed" from the eyes of the observer, and we can judge them only by the obtained results. It is for the study of these processes that the "Pion" device was created. This is an instrument for studying the peculiarities of weightlessness. Vladimir Kovalenko and I had occasion to test the first model of the "Pion" on the "Salyut-6" station. The "Pion-M" device currently operating on the "Mir" complex was /9
brought from the "Salyut-7" by Leonid Kizim and Vladimir Solov'yev.

In the "Pion" a ray of light shines through a transparent cuvette filled with a model liquid. The density of the liquid which changes non-uniformly in the course of the experiment distorts the beam, and this is recorded on photo film. In order to monitor the internal movement of the liquid, special "marks" are placed in it. These are aluminum powder particles about 20 m in diameter. During photography with the aid of a stroboscopic (interrupted) light source, a chain of bright points is formed, along which it is possible to trace the route and speed of movement of the "marker", and consequently also the internal flow in the liquid. Thus, the details of thermocapillary convection and the possible methods of combatting it are studied.

With the participation of specialists from the USSR Academy of Sciences Institute of Physical Chemistry, a series of experiments in the field of colloidal chemistry was developed. Under earth conditions, aerosols settle very quickly, and it is practically impossible to study the dynamics of their structure formation. In weightlessness such a possibility appears, and it is realized with the aid of this same "Pion" device. In the experiment "Kolosok" (Spikelet), scientists tried to study the behavior of hydro- and aerosols in weightlessness. Six transparent ampules were prepared for the experiment. Three of them were filled with distilled water. In the first they placed glass balls 10-20 m in diameter, in the second--silicon oxide particles (so-called white ash) 50 m in diameter, and in the third--aerosyl particles (a variety of glass). The other three ampules contained air with the same additives as in the first three ampules, only the silicon oxide was replaced by fluoroplast-3.

The obtained results surprised even the experimenters. The fluoroplast, spreading over the volume of the ampule, left an empty space which by its form was reminiscent of strange-looking trees. The aerosyl stuck together into rather large cakes. The glass balls formed lumps of 4-6mm in diameter and were so strong that even pellets made of stainless steel which had been specially placed in the ampules to improving mixing of the mixture during shaking could not break them up. It seems that scientists have entered a new, yet unknown field of colloidal chemistry.

Space is a vacuum and weightlessness. For almost 2,000 years Aristotle's /10
postulate ruled over man: nature loves emptiness. The first one to doubt this was Galileo Galilee. Evangelista Torricelli, a student of Galileo, discovered the vacuum and atmospheric pressure. In 1647 Blaise Pascal, having invented the barometer, forced the "Torricelli hollow" to operate.

Today the vacuum technique is used very often on Earth. Yet things are more complex with weightlessness. Although its first industrial application began as early as the 12th century, when William Watt obtained a patent on an original method of making lead shot. Drops of molten lead were dropped from a high tower, and during free fall (in weightlessness), they formed into almost perfect balls before they cooled. Under earth conditions, weightlessness may be achieved only for a short time. Space flight is a different matter. Only the development of cosmonautics has made it possible to systematically study a world in which the force of gravity is not expressed.

In mid-March the "Taymirs" prepared a modernized technological installation "Korund" for operation. It had been brought to orbit in the "Progress-28" cargo ship. They conducted a series of experiments on it. The electric heating furnace of this installation is intended for sequential work with six samples. The control system, which includes a micro-computer, makes it possible to perform experiments in an automatic regimen according to a pre-determined program. The experiments on the "Korund" are performed to develop the optimal conditions of technological processes, as well as to obtain monocrystals of semiconductor materials under conditions of weightlessness.

Life in orbit followed its course. Yuriy Romanenko and Aleksandr Laveykin brought additional equipment to the station, delivered on the "Progress" ships. They performed planned scientific experiments. "Good morning, 'Raymirs'! How do you feel?". Usually that is how the morning communication session of the FCC operator with the crew began. The sincerely warm greeting set a happy mood for the entire work day.

At the FCC, the space complex seemed to be in the palm of one's hand thanks to the telemetry. The control of the on-board systems by the crew as compared with the capacities of the ground stations is limited. Therefore, the operator /11
at the FCC, who is in communication with the crew is the source of the most varied information. He gathers information on the condition of the instruments and the well-being of the cosmonauts. He gives the necessary technical recommendations and tells about matters at home. In accordance with this he must be, on one hand, a top-class specialist, and on the other--a sensitive and tactful person capable of discerning the mood of the cosmonaut just by his voice and if necessary-- of making corrections.

And it is not all the same to the cosmonaut who sits at the communication desk. It must necessarily be a person to whom he feels kindly disposed. Generally, that is the case. Most often those who join the crew with Earth are themselves among the detachment of cosmonauts and are comprehensively preparing for an upcoming flight. Duty in the FCC for them provides invaluable lessons which will undoubtedly be useful in the future.

The flight of the "Taymirs" began a new stage in the operation of the "Mir" station--the stage of developing a complicated and constantly operating scientific-research complex with specialized modules. Yuriy Romanenko and Aleksandr Laveykin became acquainted with the first of such modules at the cosmodrome, and then they had to work on them in space. The "Kvant" (quantum) module is astrophysical by its basic specialization. It contains unique apparatus on board for studying x-ray sources in a very broad range of energies--from 2 to 800 keV. The sensitivity of the detectors makes it possible to perceive radiation whose wavelengths differ by 400 times. For comparison we may recall that within the limits of sensitivity of the human eye the wavelength of optical radiation varies by only 2 times.

All the x-ray apparatus is united into a common complex--the orbital observatory "Rentgen" (x-ray), which was created with the participation of scientists and specialists from the USSR, the Netherlands, Great Britain, the FRG and the European Space Agency. The module is also equipped with a "Glazar" ultraviolet telescope developed by scientists at the Byurakansk Astrophysics Observatory and the industrial enterprises of Armenia, with the participation of astronomers from Switzerland. The "Glazar" telescope is intended primarily for studying the activity of quasars and galactic nuclei. The electrophoretic /12
apparatus "Svetlana", although it is not related to the primary specialization of the "Kvant" module, nevertheless has been placed on board the module. It is intended for working out methods for obtaining super-pure biologically active substances.

The first effort at docking the module with the station ended unsuccessfully. The "controllers" had over-insured themselves. They programmed requirements which were too rigid into the on-board computer, and the automatics refused to respond. They quickly got down to the bottom of the matter and developed a variant for a new meeting of "Kvant" and "Mir".

While the specialists were seeking a solution, the "Taymirs" were scheduled to participate in a press conference with Soviet and foreign journalists. Such work is also included in the cosmonauts' circle of responsibilities. Correspondents from the central Soviet newspapers, TASS, APN (Novosti Press Agency), Gosteleradio (State Television and Radio), accredited representatives of France Press in Moscow, "of "Rabotnichesko delo", Prensa Latina, "Neues Deytchland", "Mond", the Syrian press agency SANA, and other means of mass information have all come to the Flight Control Center. Cosmonauts from Syria, Bulgaria and France have all come, who are preparing for flight on the orbital complex "Mir". The questions of the journalists were multi-faceted. They dealt with Cosmonautics Day, with the 20th Komsomol Congress, with the problems of a peaceful space and the prospects for development of cosmonautics, and even with the approaching birthday of Aleksandr Laveykin... At the end everyone congratulated the "Taymirs" with the upcoming holiday--the Day of Cosmonautics.

The Day of Cosmonautics. Prepared for this day, as always, was the special edition of the television journal "Man. Earth. Universe". The permanent narrator of the journal, USSR pilot-cosmonaut V. I. Sevast'yanov, came to the FCC for the communications session in order to congratulate the "Taymirs". "Thank you, Vitaliy, for your kind words and for the greeting," said Yuriy Romanenko in response. "We are celebrating our professional holiday in direct work, right here in space". He and Aleksandr Laveykin really did celebrate April 12 directly in space, in open space.

The fact was that on the second try of docking "Kvant" with "Mir", although there was contact, nevertheless the process of docking could not performed to the end. Thus, the orbital complex went out of the zone of radio visibility, presenting a puzzle for the FCC. During the break few left the main hall of the FSS. Those who were present crowded around the model of the docking unit /13 which stood here and discussed the possible reasons for the delay. During the next communication session they were able to get some information. The "Taymirs" reported that they can see one of the solar batteries of the module at a slight angle. A few more clarifying questions followed, and the specialists determined that the surfaces of the juncture frames had not pulled together only in one section, and "Kvant" was slightly tilted in relation to "Mir".

Aleksandr Laveykin, casting a final glance at the porthole before going off to rest, suddenly noticed a thin wire which was running down along the surface of "Kvant" in the direction of the juncture unit, right to the place where the juncture frames were not joining together. The situation with the wire was simulated on Earth. If it had gotten onto the guide pin, then there was a situation very similar to that which had occurred in orbit.

Other possible, and even improbable variants were also examined. For example, maybe they had forgotten to remove some cover. In principle this possibility was excluded. Every cover which must be removed prior to launch has a well marked red flag. And according to the instruction, nothing red should remain on the spacecraft. Moreover, the spacecraft is photographed from all sides before being covered by the shield. The photographs of "Kvant" showed that everything was normal. The situation could be clarified only by the cosmonauts going out into open space. The main difficulty of this venture was the unknown.

The crew prepares ahead of time for all work in open space. This preparation is done back on Earth. In the hydraulic weightlessness basin the cosmonauts thoroughly work out individual operations and the entire program of upcoming actions. During their flight, Yuriy Romanenko and Aleksandr Laveykin were to install a third solar battery onto the outside surface of the "Mir" station. Their training sessions in the hydrobasin were aimed specifically toward the solution of this concrete problem. However, unplanned ventures into open space had also been encountered earlier.

Let us recall Vladimir Lyakhov and Valeriy Ryumin, when after 6 months of orbital watch they had to go out into open space, go along the entire length of the "Salyut-6" station, and free it from a 10-meter length of radio telescope /14
antenna. Such work had not been previously foreseen. And what about the repair of the hydraulic main installation on the "Salyut-7" station? After all, then Leonid Kizim and Vladimir Solov'yev had to penetrate to the part of the station which was not intended for visits. And although they had prepared for this, many things had to be decided on site.

Usually several days are given for preparations for the crew's going out into open space. The cosmonauts closely examine and check their space suits. Work in open space, where the man is separated from deep vacuum by only the shell of the suit, forces him to be particularly careful with his "outing clothing". After all, any accidental damage to it against some cutting or piercing object may lead to depressurization. And this is a serious emergency situation fraught with dangerous consequences. Therefore, the demands for safety technology during work in open space are extremely strict.

All the instruments which the cosmonauts use during their exit are made to be maximally safe for the space suit. The edges of the exit hatch are covered with a protective ring. All potentially hazardous places are also covered on the outside surface of the station whenever possible. However, cosmonauts go out into space not for an outing, but for work. And this work is quite varied. Leonid Kizim and Vladimir Solov'yev had to cut the lining of the "Salyut-7" station with the aid of special cutters. Vladimir Dzhanibekov and Svetlana Savitskaya welded and cut metal, using a hand-held electron-beam device with beam temperature in excess of 1000°C. In order not to damage the space suit while working with such instruments, it was necessary to very carefully control one's actions. Therefore, the seeming slowness of the cosmonauts' movements during their exits are in essence the result of a consciously developed style of behavior in open space.

Just as carefully as the cosmonauts check their space suits, so they are themselves checked by doctors before going out. Work in open space is very labor consumptive and can be handled only by an absolutely healthy, physically prepared person.

After making the decision to go out into open space, the "Taymirs" were given less than 2 days to prepare for these operations. Shortly before midnight /15
of 11 April they went out into open space through the hatch of one of the peripheral docking bays on the transitional compartment of the station. First they had to install an additional hand-hold, and then go along the entire length of the station to the place of juncture of "Mir" with "Kvant". "We are at the edge of the instrument compartment, at the docking unit," reports Yuriy Romanenko. "There is no wire stuck in it. It doesn't go as far as the juncture unit. There is a slight displacement of the docking ring upward and to the side, by about a centimeter".

Well, one version has been discounted. Yet the reason has not yet been discovered. The FCC makes a decision and V. V. Ryumin relays the plan of action to the "Raymirs". "You stay at the edge section while we give the order for moving out the arm. First by 150 millimeters, then we will see, then all the way to the end. Check the condition of the covering on the ruff of the docking unit. Maybe one has gotten caught and bent. Maybe that's what is in the way". "Mir" and "Kvant" began to slowly move apart, remaining as before mechanically joined with the aid of the catches on the arm of the docking unit.

And then suddenly we hear an exclamation of surprise from Aleksandr Laveykin. He saw some kind of foreign object in the docking assembly. "It is about 40 by forty centimeters", clarifies Yuriy Romanenko. "Can you reach it?" asks the FCC. "We will if you move the objects farther apart," Aleksandr Laveykin assures them. "I can already touch it with my hand". "We are moving them apart. Be careful," warns the FCC. "What does it look like?" "It looks like a bag," answer the "Taymirs", "or something wrapped in a rag".

So the "Taymirs", in cleaning out the docking assembly, had to work with tools. They cut with a knife and they sawed... The pieces of this foreign object flew off, and we will never know what this was exactly. The subsequent process of juncture this time, as they say, went according to the standard plan, and ended in full juncture of the "Kvant" module with the "Mir" station. Convinced that all had ended well, the "Taymirs" returned to the station.

By tradition, on holidays relatives and friends of the cosmonauts working in orbit come to the FCC. This time tradition was broken. Yuriy Romanenko and Aleksandr Laveykin, having successfully dealt with their difficult task, /16
slept soundly. Meanwhile, we watched the special edition of the television journal "Man. Earth. Universe", where the "Taymirs" talked with us and performed their own song for us accompanied by the guitar, the first song written in space:

Having burned out, the stages drop away,
Calling us to cosmic speeds.
Now my turn has come to measure
My love for you, my native Earth.
With my is my friend, tried and true,
My guitar and much work to do,
And our flight is measured not in days,
For the whirlpool of white stars circles around us.

> I will fall onto the grass
> I will breathe to my heart's content,
> I will drink the river water, when I return.
> I will fall to the ground,
> I will embrace my friends,
> I will sing and love, when I return.

Space is work, and we must say directly--it is not one of the easy jobs. It is especially hard in the first days, and even later there are pressures. There are many things to be done in the cosmic house. Therefore, the flight program is flexible. If some immediate concerns pile up, then it is possible to change the program. Due to the delay with the docking of the "Kvant" module, so as not to disrupt the schedule of cargo ship runs along the route of Earth to space, it was necessary to put off the planned work of the "Taymirs" in open space. According to the plan, they were to install a third solar battery which the module had brought on the base unit of the orbital complex. But now they first had to unload the "Progress-29". The space walk was changed over to the start of May, and in view of all the pressing matters were able to finally implement it only in June.

No matter how thoroughly the flight program is worked through, it is impossible to eheck everything that must be done in space, especially at first, under earth conditions. Thus, for example, how can we check on Earth the methods of controlling an almost 50-ton machine in weightlessness with the aid of gyroscopic stabilizers (gyrodynes)? Moreover, the gyrodynes are installed on a module, and not on the base unit, so that the guidance system is peripheral. In combination with the on-board computers, the gyrodynes may solve a wide range of problems, freeing the crew for other work. This does not entail the expenditure of fuel and does not pollute the environment surrounding the station. /17
This explains the interest which the creators of space technology as well as the suppliers of experiments which demand long and precise orientation of the entire orbital complex, have in the guidance system using gyrodynes.

Thus, for example, in order for the telescopes of the "Rengtgen" observatory to work to their full capacity, it was necessary first of all to teach the "Mir" complex to fly using gyrodynes. The developers of the "Rentgen" observatory had long awaited their hour, and their impatience was understandable. The fact was that at the end of February in the depths of the Universe, in the Great Magellan Cloud, there was a supernova. In actuality, it had flared not at the end of February 1987, but about 180,000 years ago, and only now had the light reached Earth. A supernova is a phenomenon which presents great interest for astrophysics. And here in orbit was q unique complex of x-ray telescopes (as we know, the earth's atmosphere does not let through radiation in the x-ray range). When the program of work on the "Rentgen" observatory was being planned, no one could have predicted such a success. It is as if it was made to order.

The first sessions of operation of the x-ray apparatus (they were held on 8 and 10 June) encouraged scientists. The director of the "Rentgen" program, USSR Academy of Sciences corresponding member R. A. Syunyayev did not hide his joy. "After the explosion of the Supernova," he said, "a shell weighing more than 15 of our suns was formed around its nucleus. This shell, like a concrete wall, retains x-rays. As yet the Supernova is visible only through optical telescopes. But the instruments of the Japanese satellite, the Soviet satellite "Astron" and the "Kvant" module are all aimed at this quadrant of the sky. We are waiting for the shell to become transparent to x-ray and gamma rays, when the Supernova will shine in the range which is of interest to us. The x-ray range is much more informative than the optical, and possibly will allow us to determine what remains after the explosion--a neutron star or a black hole?"

By its instrumentation, the "Kvant" module greatly surpasses other space apparatus. The gyrodyne guidance system has given it stabilization within the limits of 1'. It is interesting that the readings of the on-board orientation /18
instruments may be verified by known x-ray sources, which makes it possible to increase the precision of operation of the new guidance system. Thus, astrophysics in return for the aid of cosmonautics, in turn helps to develop space technology.

Being the most ancient of the sciences, astronomy has studied the heavenly bodies for many centuries according to the light of electromagnetic radiation which they emit in a very narrow wavelength interval, which is not screened out by the earth's atmosphere and to which the human eye is sensitive. Placing the telescopes beyond the boundaries of the atmosphere, into the reaches of space, has opened up broad perspectives for astronomical research. It has become possible to study the heavenly bodies in infrared and ultraviolet ranges, and in gamma- and x-rays. The greatest portion of radiation in these wavelength ranges belongs to astrophysical objects which are found in totally different physical conditions than ordinary stars, which emit the lion's share of their energy in the light rays which are customary to us.

Following the "Rentgen" observatory, the ultraviolet telescope "Glazar" undertook the study of the starry sky. It operates in the so-called far ultraviolet range, whose radiation is also not allowed in by the earth's atmosphere. It sees an entirely different picture of the starry sky than the one which is presented to the human eye. The great majority of stars here is simply absent. Only rare hot stars remain, with surface temperature of several tens of thousands of degrees Kelvin. Ultraviolet photographs of the sky will also show galaxies which have a significant number of hot stars. Strong ultraviolet radiation is present in quasars, as well as in galaxies with active nuclei.

The phenomenon of the activity of galactic nuclei, which was predicted several decades ago by Academician V. A. Ambartsumyan, is inherent in objects found in the non-stationary phase of their development, when acute changes are taking place. These processes are accompanied by powerful explosive occurrences and strong radiation emission. One of the manifestations of their activity is also the excess ultraviolet radiation of quasars and galactic nuclei. The primary task of "Glazar" was to seek out just such objects. Along the way /19
it was also to study ultraviolet radiation of other astrophysical objects as well.

For "Glazar" to operate, the "Mir" orbital complex first had to be turned in the approximate direction of the given section of the sky. Then the "Glazar" instruments begin their operation. They fix upon the brightest star within their field of vision, and maintains the telescope with a precision of around 2" in the process of observation, despite the relatively great vascillations of the entire orbital complex in relation to it. The results of the observations are recorded on photographic film, which the cosmonauts bring back to Earth. "In order to fulfill the entire 'Glazar' program," said the director of these operations Professor G. M. Tovmasyan, "it is necessary to get several tens of thousands of pictures, which in all probability will require several years". Thus, there will be enough work for the second main expedition, and for the future masters of the "Mir" complex as well.

In accordance with the program for space materials science, Yuriy Romanenko and Aleksandr Laveykin performed a series of experiments on the "Yantar'" installation. This is already the third generation of space installations for application of metallic coatings in a vacuum, created by the Institute of Electric Arc Welding imeni Ye. O. Paton. The first of these began operating in 1979 on the "Salyut-6" station. In this installation the melt of the evaporated material was held in a special construction--a crucible--with the aid of the forces of surface tension. With the aid of an electron-ray gun it was heated to the temperature of vaporization. Through a system of diaphragms the vaporized material went onto one of the replacable linings, where it condensed, forming a coating with thickness determined by the time of sedimentation. Such a space device, unlike its earth analog, does not need a cumbersome vacuum chamber. After all, there is sufficient vacuum outside the orbital station, and this circumstance is a benefit to the researchers.

The behavior of liquid under conditions of weightlessness takes on a very obstinate character. To "tame" the molten metal, to force it to turn into a vapor and to settle uniformly--this task is not a simple one. Nevertheless, experiments have shown that coatings obtained in space are no worse, and in a number of cases even surpass earth analogs. This is of practical importance for cosmonautics itself. In the course of time, the protective coatings of /20
spacecraft began to disintegrate and, of course, we must seek ways of restoring them in the course of the flight.

A second installation, the "Isparitel'-M" (Evaporator-M) was developed on the "Salyut-7" station. And now the "Yantar'" has appeared on the "Mir" complex. The principle of its operation is based on the same method of electron-beam fusion of metals under conditions of a space vacuum, with subsequent condensation. In the experiment, a 3-meter roll of polymer film is used as the lining. By means of repeatedly pulling it through a flow of copper vapors, it was possible to obtain copper foil of impressive dimensions.

The "Paton group" generally has extensive and varied experience in work in space. As early as 1969 the first "Vulkan" space installation, intended for electric arc welding of metals, operated on the "Soyuz-6" craft. They are also the creators of the universal hand tool which the cosmonauts used to perform cutting, welding and soldering of metals and application of coatings, developing the principles of expanding various framework constructions and building solar batteries.

A significant place in the research work of the "Taymirs" belonged to geophysics. The Earth is beautiful from space--the cosmonauts all unanimously agree to this. In order to truly evaluate its enchanting beauty--black space and the blue strip above the earth's horizon--you have to see it with your own eyes. In one earth day you have time to see 16 sunsets and sunrises! And /21
if it is a solar orbit, then the Sun practically never sets. Thus, it turns out that you are flying over the Earth most of the time, greeting or leaving the dawn. The crews always enjoy engaging in geophysical experiments: the observations of the earth's surface, the studies of the seas and oceans, and the study of the atmosphere.

From out here, from space, when I was convinced with my own eyes that the Earth is a ball, just a little bal in the endless reaches of the Universe, it suddenly seemed painfully helpless to me. With the reserves of atomic and other weapons which have been stockpiled on Earth, this ball can be so easily broken, leaving in space just another lifeless asteroid belt. It is specifically when you are in orbit, you might say, that you can physically, with all your being, feel your responsibility and that of all mankind for peace on Earth, on our wonderful planet. If man must expend his efforts on struggle, then let it be a struggle for life, for the beauty of Earth and for its well-being.

It is enough to make one orbit in order to see that there are storms raging on Earth, hurricanes racing over it, forest fires raging on it, volcanoes awakening, rivers spilling over and floods engulfing the cultivated fields. Our planet so desperately needs a careful and masterful attitude. It needs human kindness. Ho, it is not endless for human waste and egoism, and every river polluted with harmful waste is like a blood vessel on its wonderful body which has been placed out of commission, and this section is then doomed. And since everything on Earth is mutually related, their are no great or small losses--all of them threaten to be irreplaceable.

The International Target Integrated Project entitled "Study of the Dynamics of Geosystems by the Long-Range Methods" is devoted to a careful attitude toward nature, and toward the prudent use of its resources. Within the framework of this project, three aerospace experiments have been conducted: "Gyunesh-84", "Kursk-85" and "Geoeks-86". The first two of these were conducted on the territory of the USSR, and the third on the territory of the GDR. The next, fourth, experiment, has been named "Telegeo-87". Two proving grounds on the territory of Poland have been selected as the site for this experiment. Aside from Polish specialists, their colleagues from the PRB, GDR, Cuba, USSR and /22
CzSSR participated in this experiment.

At the "Narev" proving ground (a region in the city of Belostok), work was being performed on four key sectors from 15 May to 3 June. Its purpose was the study of the dynamics of the state of agricultural and natural vegetation under conditions of pereglacial water-logged valley of the northeastern part of Poland, the study of the current state of the reclaimed and non-meliorated agricultural systems. Photography of these sections was performed with the aid of automatic satellites of the "Kosmos" series. At the same time, airplane measurements from different altitudes under the satellites were performed as well as ground-based measurements of the characteristics of the cultivated soil surface, the basic agricultural crops, the natural vegetation, and detailed hydrological and geomorphological studies. The work was concluded with the creation of a series of large-scale thematic maps, which will be used by the planning organizations of the Belostok authorities for developing measures for the rational application and protection of the land resources.

The second part of the experiment was conducted from 26 June through 15 July at the test site of "S'reda Shlenska" (in the region of the city of Vrotslav). During these studies, methods were developed for determining the structure of the sowing of primary agricultural crops and their condition by aerospace means of long-range sounding of the Earth, as well as methods of determining the structure and dynamics of land use under various natural conditions of southwest Poland. The crew of the "Mir" orbital complex also participated in this work. To photograph the test site, the "Taymirs" used a KATE-140 wide-format camera, hand-held cameras, and the MKS-M multi-zonal spectrometer. Along with satellites of the "Kosmos" series, the "Meteor-Priroda" satellites also participated in the experiment.

The results of these works will be used for purposes of agricultural monitoring of the regions of southwest Poland and analogous regions on the territory of other socialist countries. This will make it possible to optimize the management of agricultural production in the process of seasonal and perennial functioning, and to increase the accuracy of crop prediction for the basic cultures being raised. After completion of the studies on the "Telegeo-87" /23 experiment, an overall comparitive analysis will be conducted comparing the results of solution of national economic problems for the southwest and north-east of Poland, which differ significantly by their natural conditions and by the character of application of natural resources.

International cooperation has long been a characteristic trait of Soviet cosmonautics. The Soviet Union was the initiator of many projects in which the scientists of socialist and capitalist countries participated. It is no accident that the first international crew was launched from the Soviet cosmodrome. Baykonur has launched into space representatives from the CzSSR, PPR, GDR, PRB, HPR, Socialist Republic of Vietnam, Cuba, Mongolian People's Republic, SRR, France and India. On 22 July 1987 it was the turn of the citizen from the Syrian Arab Republic.

The Syrian cosmonaut, Muhammed Faris and his back-up Munir Khabib are pilots. The aviation brigade in which they served is considered to be the best in the Syrian air force. When the cosmonaut selection began, the pilots were not told what the medical examination was for. But they guessed when they saw that it was much more complete and extensive than the previous flight medical commissions. In October of 1985, Muhammed Faris and Munir Khabib began their studies at the Center for Cosmonaut Training imeni Yu. A. Gagarin. The main crew was comprised of Aleksandr Viktorenko, Aleksandr Aleksandrov and Muhammed Faris. The back-up (double) crew was Anatoliy Solov'yev, Munir Khabib and I.

Of the main crew, only Aleksandr Aleksandrov had experience in work in space. Together with Vladimir Lyakhov he spent 150 days on the orbital station "Salyut-7". And now Aleksandr was preparing for a short flight by current standards, only 8 days, but everything turned out differently. He had to replace the on-board engineer of the main expedition, Aleksandr Laveykin, and together with Yuriy Romanenko to continue the space marathon on board the orbital complex "Mir".

During one of the medical examinations, changes were detedted in the specifics of cardiac activity regulation of Aleksandr Laveykin. The analysis which the doctors later performed after his return to Earth allowed them to conclude that we were speaking not of an illness, but of peculiarities in the /24
adaptation of the human organism to conditions of prolonged flight. However, it was possible to determine this only on Earth. I understood Sasha Laveykin when he asked them to leave him in orbit, but I also understand those who made the decision to replace him. Each of us can and has a right to risk our health, but only our own. The health of a comrade is not subject to any risk. That is the law of our cosmonautics.

On the eve of the launch one of the journalists present asked Muhammed Faris the question: "Sometimes we hear that foreign cosmonauts are given the role of passengers on a spacecraft. They work only on board the station, performing their experiments. What can you say about this?" Aleksandr Viktorenko and Aleksandr Aleksandrov interceded for their crew comrade, and for his colleagues from other countries. "It's too bad that you think that a cosmonaut-researcher has nothing to do on the ship. He is trained in such a way that if needed he can perform the duties of the other crew members. But even during a standard flight he has a well defined circle of responsibilities on the ship. For example, he is responsible for the operation of the crew's life support system, the system of ship's thermoregulation, and for communications..."

I would say this circle of responsibilities is even wider. The "Soyuz" spacecraft are capable of going the entire way from Earth to the orbital station in automatic mode, i.e., without the intervention of the crew. Thus, as long as the automatic instrumentation is functioning normally, all of us in the ship are in the role of passengers. However, we are such passengers which carefully control the operation of the on-board systems and who in case of necessity are ready at any moment to assume control.

The Soviet-Syrian crew (call-name "Vityaz'") was launched on 22 July,and 24 July exactly on schedule docked at the docking bay of the "Kvant" module. The "Taymirs" greeted the "Vityaz'" in the module. This meeting was broadcast to Earth with the aid of an on-board television camera. After one orbit we saw them in the working compartment of the base unit, so to speak, in dress circumstances. The commander of the united crew Yuriy Romenenko reported on the start of joint operations on board the "Mir" complex.

As always, the crew of the visiting expedition began its work on board the orbital complex primarily with the medical experiments. After all, it was the /25
acute period of adaptation, and the medical experts did not want to pass up such an opportunity. Particular attention was given to the study of the functions of the cardiovascular, respiratory and muscular systems, since the experience of space flights has shown that weightlessness primarily affects specifically these systems.

The Syrian specialists were primarily interested in those technological experiments which could give tangible practical results. These were the operations on space materials science, which opened the way for getting to know many processes in earth technology. However, in space materials science experiments are rarely encountered which are associated with simultaneously obtaining a large number of relatively small crystals, i.e., with the study of the so-called mass crystallization. Nevertheless, on Earth mass crystallization is one of the basic means of purification of substances, for obtaining most materials in chemical technology (powdered chemical reagents, fertilizers, toxic chemicals, table salt, sugar, etc.).

Mass crystallization is practically always accompanied by the unification (aggregation) of crystals into spatial structures of various complexity, which largely determines the properties of the end product. The study and application of the processes of structure formation under Earth conditions is hindered to a significant degree by the presence of the force of gravity, which leads to the sedimentation of the particles in the liquid and which hinders the manifestation of aggregation mechanisms. Weightlessness eliminates this shortcoming. The idea of growing crystals from aqueous solutions in weightlessness became embodied in the Soviet-Syrian experiment called "Pal'mira" in honor of one of the most famous cities in ancient Syria (today this is the site of the city of Tadmor).

The Syrians have great respect for their country's history and honor the past centuries, the ancient creations of the people, and the people themselves, who made a contribution to the fund of human knowledge. "Syria is an ancient country," Muhammed Faris told us. "Archeological excavations testify to the fact that even several thousand years before our era there were human settlements on Syrian soil. It is enough to name the ruins of ancient Ugarit. This north /26
Phoenician city-state was located not far from the large modern day Syrian port of Latakiy. However, the stones silently preserve the face of the past, while the legends and legacies still reflect the soul of the people. Ask any Syrian: "What is more valuable than gold, stronger than Damascus steel, what is not ruled by time?" And he will answer in one word--friendship!"

In conducting the "Pal'mir" experiment, it was necessary to mix solutions of different concentration, which is quite difficult to do in weightlessness. A simple and original solution was found: they took a pair of medical syringes and joined them wit- a plastic tube with a clamp. On earth the syringes were filled with the solutions, and the cosmonauts in orbit had only to open the clamp and make a vew movements with the plunger to mix the initial liquids. After mixing, the growth and aggregation of the crystals begins. The Soviet-Syrian crew brought seven pairs of such filled syringes with them.

In one of the television sessions we saw Muhammed Faris engaged in the "Pal'mir" experiment. "It is getting to be," Aleksandr Aleksandrov commented on the experiment, "that someday space, perhaps, will give us, if we can express it that way, our own bones and our own teeth". Yes, experiment in the crystallization of substances in weightlessness is today being performed with hydroxylapatite. Its microcrystals comprise the reinforcement base of bone and tooth tissue. And work on obtaining synthetic hydroxylapatite leads to the creation of reliable dentures, and bone tissue replacements which are not rejected by the organism.

Two other technological experiments were conducted on the Soviet-Czechoslovakian multi-functional installation of a new generation, the "Kristallizator" (Crystallizer). The five high-capacity electric heaters of this device maintain a stable temperature in the range of up to $1000^{\circ}C$. It is possible to simultaneously process 19 of the most different samples--from glass to semiconductors. Each material is ensured an individual regimen of temperature and pressure, rate of movement of the ampules, etc. The installation is equipped with a microprocessor capable of independently controlling its entire operation in an automatic mode according to a given program.

In the experiment "Kas'yon", eutectic alloys of a model material of aluminum- /27
nickle are obtained by the method of directed crystallization. The name of the experiment is no accident. Everyone has heard of the specific advantages of Damascus steel, whose secret of manufacture, unfortunately has been lost. Kas'yon is the name of the mountain in Damascus, and the "Kas'yon" experiment is directed at obtaining new types of structural materials capable of replacing expensive alloy steels. Eutectic alloys with directed crystallization possess unique properties and retain their structural stability and physico-mechanical characteristics up to the melting point, which makes it possible to use them as refractory materials. As a result of the study of the space samples and their comparison with earth analogs, new information will be obtained on the peculiarities of the processes of hardening of metallic alloys under conditions of weightlessness.

The prospects for obtaining high-quality semiconductor materials in space are the goal of the experiment "Afamiya", which is named after an ancient part of Syria. In the course of this experiment, directed crystallization of gallium antimonide is realized.

The international crew continued the biotechnological experiments begun on the "Salyut-7" station 5 years ago. In these years, Soviet scientists created a series of space biotechnological installations: "Tavriya", "Genom", "Robot". Today the new automated installations "Svetlana" and "Ruchey" (brook) are operating on board the "Mir" complex. The first of these is engaged in the isolation of active microorganisms which produce fodder antibiotics for the application of animal husbandry. The "Ruchey" installation is based on the process of electrophoresis in a layer of liquid, which moves across an electrical field. Its advantage is the significant increase in the productivity and purity of the obtained preparations. The crew performed purification of antiviral interferon and anti-influenza preparation for obtaining experimental batches of antiserum.

Scientists hope that these experiments will help to create large bio-technological installations in the next few years, which will be used on special /28
modules as part of orbital complexes, and then to introduce a permanently operating industrial plant-complex for the production of unique medicines and preparations for the needs of public health and other sectors of the national economy.

Long-range sounding of the Earth was represented in the flight program by the "Evfrat" (Euphrates) experiment. It is specifically with long-range sounding that the way toward space study began in Syria. As early as 1958, with the aid of the USSR, Syrian specialists began to conduct aerial photography of their territory. Long-range sounding with the aid of aviation made it possible to discover large mineral reserves in various regions of the republic. In the mid-70's there were laboratories created in Syria which engaged in processing the results of the aerial photographs and the information obtained from space. On the basis of the space photographs, as well as the data of ground-based studies, lithological, morphological and tectonic maps of the Syrian coast in a scale of 1:50,000 were created. In 1978 the National Committee was organized in Syria, transformed in 1986 into the General Administration for Long-Range Sounding, which is responsible for the work associated with space, aerial, and ground-based photography of the territory and performs analysis of the obtained data for use in survey and assimilation of natural resources and environmental study.

The task of the "Evfrat" experiment included the study of the agro-industrial resources and the agricultural crops in the basin of the Euphrates River and the Syrian desert, the identification of regions which are promising for exploration of minerals and water reserves in the Arab-African fissure and in this same Syrian desert, the study of the forest reserves of the northwestern part of Syria, the inland water reservoirs (reservoirs of Al-Asad and Baas, Lake Kattina), the pollution of the atmosphere and the shoreline aquatoria, as well as the comprehensive cartography of the SAR territory. At the same time as the photos are taken from on board the "Mir" complex, Syrian specialists were conducting aerial photography and ground-based measurements of the studied areas. The obtained results will be used in the interests of science and various sectors of the country's national economy. "The 'Evfrat' experiment," said /29 Muhammed Faris, is most important for the practical needs of our country. It is generally acknowledged that we can really help in solving the problems facing our people".

The study of the upper atmosphere and the ionosphere for the purpose of improving their mathematical models was performed in the "Bosra" experiment (the name of an historical site in S-ria where a large ancient amphitheatre has been preserved). The high precision apparatus for this experiment was developed by Soviet and Syrian specialists.

Time flew by as the cosmonauts were engrossed in the work. And although the program was very full, the cosmonauts tried to make time to sit together and talk in the evenings, to play the guitar and sing the songs which they had grown to love back on Earth. Aleksandr Laveykin told that this situation reminded him of an evening campfire, during which good, hearty comrades would gather roung. However, the time for departure had come. Aleksandr Laveykin changed call names with Aleksandr Aleksandrov, and the crews also changed ships. The "Vityaz'" were to return to Earth in the spacecraft "Soyuz TM-2", since the resource of its on-board systems was running out. They left their more "fresh" ship, the "Soyuz TM-3", for the "Taymirs"--Yuriy Romanenko and Aleksandr Aleksandrov, who still had many months of orbital duty ahead of them.

It is true that on 31 July the "Taymirs" also left their orbital home. At 2 hr. 27 min. 40 sec. the "Soyuz TM-3" craft with Yuriy Romanenko and Aleksandr Aleksandrov left the docking bay located on the "Kvant" module, after which by command from the FCC the complex made a 180° turn, turning its passage compartment toward docking. The re-docking, which is generally a standard operation, was being performed for the first time on the "Mir" complex. At 2 hr. 47 min. 00 sec. the telemetry registered the touching of the space craft, juncture, and checking of the air-tightness of the juncture. All this went without problems, and the crew returned to the station accommodations. On 3 August at 23 hrs. 44 min. 11 sec. "Progress-31" was launched to greet the "Taymirs". On 6 August at 01 hr. 27 min. 36 sec. it approached the cargo bay of the orbital complex, i.e., the juncture assembly on the "Kvant" module.

As we have already said, a significant place in the flight program of the /30 "Mir" complex belonged to astrophysical experiments with the use of x-ray and ultraviolet apparatus of the scientific module. However, considering the interest of astronomers throughout the world in the Supernova in the Great Magellan Cloud, Professor G. M. Tovmasyan, director of the astrophysical experiment, which is being performed with the aid of the ultraviolet telescope "Glazar" yielded his experimental sessions to his colleagues. This was truly a noble act. After all, by that time the x-ray telescopes had conducted around 170 sessions and gathered over 60 hrs of work, while "Glazar" had only had 4 hrs in 9 days.

The fact was that on 10 August the sensitive instruments of the orbital international observatory "Rentgen" first recorded x-ray radiation of an unusually harsh spectrum from the region of the Supernova. Could it be that that long-awaited moment had come when the the scattering cloud from the exploded star had become transparent to the x-ray range?

The head of the experiment, USSR Academy of Sciences corresponding member R. A. Syunyayev did not hurry in drawing any conclusions. "In the Great Magellan Cloud," he said, "there are four x-ray sources, and one of them is only 0.6^{o} from the Supernova". To determine the true source of the radiation, scientists continued to slightly turn the "Mir" orbital complex in order to exclude from the field of vision of the x-ray telescopes the source neighboring the Supernova. The control system of the complex, which was based on the principles of force gyroscopy, brilliantly handled this precision operation. As a result, everyone became convinced that the x-ray radiation really was coming from the Supernova.

We must say that in the recent past far from everyone believed in the possibility of controlling such a complex assembly of space apparatus with the aid of gyrodynes located at a considerable distance from the center of the mass of the "Mir" complex. The work in orbit refuted their doubts. The high precision of orientation, the possibility of maintaining a given oriented position for a limited time evoke deserved admiration for modern Soviet space technology.

The stations of the previous generations used jet engines as the executive organs in the guidance system, and fuel was required for their operation. Its /31 expenditure increased with increased precision of orientation, and to replentish the fuel supplies to the "Salyut-6" and "Salyut-7" stations, regular runs of "Progress" series space tangers were needed. But even with 6-8 "Progresses" a year, the "Salyuts" could not fly in an oriented position for more than 5-10% of their overall time spent in orbit. To realize the program of astrophysical research which is being performed on the "Mir" complex was impossible on such stations.

It was necessary to develop a new system for controlling the movement of the orbital complex, whose operative organs would not expend working fuel. Our country's cosmonautics already had experience in the development of such systems with electromechanical operative organs, which required only electrical energy for their operation. This energy was obtained from the solar batteries or on-board storage batteries. Thus, for example, in orbits around the earth, automatic satellites of the "Meteor" type are constantly being used. These are equipped with an electromechanical three-flywheel system of orientation and stabilization. The experimental system of orientation with a round engine-flywheel in a magnetic suspension was used on the "Salyut-3" and "Salyut-5" stations.

However, for the "Mir" complex the moments of inertia are significantly higher than for the "Salyuts", and under such conditions it is energetically more expedient to have power gyroscopes than engine-flywheels. The gyrodynes installed on the "Kvant" are very complex electromechanical devices whose rotor turns in a magnetic field of guiding electromagnets. The mathematical model of the guidance system determined the strict spatial installation of six gyrodynes on the module, and on the basis of this model algorithms were developed for the on-board computers, which are part of the guidance system. These algorithms consider the retention of guidance without the expenditure of the operating body with all types of orientation of the "Mir" complex. Also, the changes in the program of computer operation may be introduced from Earth, as well as by the crew.

In September the "Taymirs" participated in one other international experiment, the "Aneks-87", which was conducted on the territory of the CaSSR. This was the /32
first inter-state experiment on the control of environmental pollution. The problems of environmental pollution have long ceased to be domestic ones. The air currents do not know state boundaries, and spread harmful pollutants to hundreds and even thousands of kilometers. Thus, if one country takes all the necessary precautionary measures, it still cannot feel safe in the surroundings of its neighbors who upset the ecological balance. In this joint Soviet-Czech

experiment specialists decided to determine the constant paths of the so-called trans-boundary transfers from sone countries to others (for example, from the CzSSR to the PPR, GDR, Augstria, USSR and back).

The presence of harmful admixtures in the atmosphere, on the surface and in the water was determined with the aid of ground-based measurements, which were performed by specialists of the Czech Administration of Geodesy and Cartography and the CzSSR Hydrometeorological Services. The task of the Soviet specialists from the Institute of Applied Geophysics, the USSR Goskomgidromet (State Committee on Hydrometeorology), the USSR Glavkosmos (Main Space Administration), pilors and engineers of the Myachkovskiy air detachment became aerial and orbital control. The flying laboratory was located on an Il-14 airplane. It measured, specifically, the transfer of pollutants from the FRG over the border to the region of the Czech Forest and Shumava, as well as the profile of pollution of the airspace over Prague.

Space monitoring was implemented with the aid of the Soviet unmanned Earth satellites and from on board the "Mir" orbital complex by cosmonauts Yuriy Romanenko and Aleksandr Aleksandrov. It is specifically space observations which in the future will play the primary role, and the information obtained from space in the form of photographs and spectrograms will be analyzed on computer according to programs developed in the course of prior experiments. And then the machine will itself find and interpret in quantitative units the details which are already familiar to it, and thereby control over the environment will be more effective and simpler. Ground-based and aerial measurements will either cease altogether, or will be used only for clarifying individual fragments of the overall map of the ecological situation.

Interest in observations of the Earth from space is being shown by many /33 countries at the present time. Space information is successfully being used for solving pressing earth problems. In the past, cartographers spent centuries compiling the outlines of the continents, the oceans, the seas and other geographical objects. However, spacecraft are capable of photographing the surface of the entire planet in several orbits. In our dynamic time, only a glance from space is able to monitor the rapid growth of cities, industrial centers, the development of road networks, and the changes in land application. If we use only traditional land-based methods as before, then before the map compiled on the basis of these data reaches the user, it will be hopelessly out of date.

And even aerial photography will be unable to solve this problem.

In our country, all the materials of space photography, which are intended for long-term application, are sent to the Main Administration of Geodesy and Cartography under the USSR Council of Ministers, and to the State Scientific-Research Center "Priroda" (Nature). Here the space photographs and materials obtained by topographo-geodesic expeditions, with the aid of computers and stereo-photogrammetric equipment, are transformed into topographic and thematic maps for the study of the Earth's natural resources. Hundreds of organizations of various ministries and departments receive this information from the GUGKa, and use it in the national economy.

With the aid of space photography, for example, it has been possible to compile detailed maps of inaccessible regions of Pamir and Tyan-Shan, to identify previously unknown pasturelands, and to outline a plan for the construction of new tourist bases and location of recreation zones. Using the thematic space maps and the synthesized multi-zonal photos, underground deposits of fresh water have been found in the semi-arid Prearal region. Specialists evaluate the economic effectiveness of using space information in the national economy to be 5 rubles of profit for every 1 ruble of expenditures.

To photograph the earth's surface and the World Ocean, Yuriy Romanenko and Aleksandr Aleksandrov used a wide-format stationary photo camera KATE-140, hand-held cameras, and the MKS-M multi-zonal spectrometer. A new photographic camera also appeared on board. It was delivered by one of the "Progresses". This /34
was a medium-format camera, the "Sever" for determining non-uniformities in the earth's surface in refracted solar rays. The objects of photography became various sections of the Soviet Union territory: the Ukraine, Moldavia, the Caucauses, and the Central Chernozem regions of Russia, as well as the Volga region, the Precaspian depression, the Southern Urals, South Central Asia, the Central Asian Republics, South Siberia, and the Far East.

From year to year, experiments are performed on the application of space photos in the interests of agriculture. The photography of the "standard" fields is performed from various altitudes and at different times. Here, the task was set of learning to determine from the space photos the degree of readiness of the grain crops, their lodgeability, plant diseases, the condition of the soil, etc. Everyone happily speaks of the usefulness of this endeavor, but for some reason it does not reach the stages of widespread practical application. Academician B. V. Raushenbakh said the following in this regard: "I know of cases where our agricultural specialists literally became frightened when they learned that it is possible to reliably and quickly determine the areas taken up by a certain crop culture, the needs for irrigation, the state of the crops, and the harvest prospects. After all, this is a sort of openness in questions, as life has shown us, that are rather touchy, and in general not everyone likes openness".

On 22 September at 2 hrs 58 min. 00 sec. the "Taymirs" said good-bye to the cargo ship "Progress-31", which at 3 hr. 22 min. 00 sec on 23 September turned one its engines for the last time, leading the ship out of orbit. The next day, on 2 hr. 43 min. 54 sec. the next cargo ship, "Progress-32" set off into space, which completed its unmanned flight at the "Mir" docking complex on 26 September at 4 hr. 8 min 15 sec. Along with the traditional cargo, the "Progress-32" also brought the cosmonauts a large, ripe watermelon. Such presents in orbit, especially during a long flight, are very welcome. This is not only a pleasant variation in the menu, but something more--a sense of their comrades' concern back on Earth, a feeling of earth life itself.

Starting 1 October, at the insistence of the doctors, the "Taymirs", in spite of their objections, reduced their work day by 1 hour. The fact was that up until now the longest manned space flight was the achievement of the crew comprised of Leonid Kizim, Vladimir Solovyev and Oleg At'kov, set in 1984. /35
It comprised 236 days 22 hrs. 49 min. 00 sec. And then on 30 September 1987 at 23 hrs. 27 min. 16 sec., Yuriy Romanenko broke this record. It is true that he became the officially acknowledged record holder somewhat later, when the former record had been exceeded by 10%--those were the requirements of the International Aviation Federation.

Man's prolonged presence under conditions of weightlessness is possible only with reliable prediction of the state of his health and work capacity. Today one rarely hears discussions in the medical provision group about changes in cardiac volume, loss of calcium from the bone tissue, or muscle degradation. These phenomena, which at the dawn of manned flights presented considerable difficulties, have today more or less been settled. Now we know how to combat them by using various means of prophylaxis of the effects of weightlessness. Encouraging results have been obtained also in ground-based experiments. Thus, at the Institute of Medico-Biological Problems, volunteer researchers did not get out of bed for a year, and during this time their organisms underwent the same changes as cosmonauts under the effect of weightlessness.

Today doctors are more concerned with the psychological aspects of long-term space flights: the limited volume of the orbital stations, the repetitive monotony of everyday tasks in space, the absence of environmental surroundings to which people have become accustomed since childhood. Doctors now devote particular attention to Yuriy Romanenko as a person who is travelling the formerly untrodden path of space longevity. Understanding this fact, the "Taymir-1" does not hide his feelings. "Of course, fatigue makes itself known. Before, for example, I never noticed the noise from the ventilators, but now, it happens, that it wakes me up at night... Earth already knows about these difficulties of mine, and Sasha Aleksandrov also treats me carefully. If I do not wake up in time, he tries not to wake me".

On 2 October in Moscos the international forum on "Cooperation in Space in the Name of Peace on Earth" was held. There were 400 foreign and 200 Soviet scientists participating in it. It summarized the 30-th anniversary of the space era, which began with the launch of the first artificial Earth satellite by the USSR, and discussed the prospects for further space activity of man. We might add that aside from the specialists whose activity is directly tied /36
with the study of space, there were also many writers and artists, as well as representatives of the humanities, at the forum.

The forum participants discussed a broad range of questions: "Space and Science", "Space and Economics", "Space and Global Problems", "Man in Space". These were the topics of their discussions. Particular interest was evoked by the by-stage program of study of Mars, which is to be concluded with a flight by an international crew to this planet. The forum participants unanimously supported the proposals of S. Eisenhower, president of the Washington Institute of International Relations, to proclaim 1992 the International Year of Space. The forum concluded its work on 4 October, and on this day the television link between the "Forum and the Mir Complex" was held. During the direct television link, the "Taymirs" spoke with the Soviet and foreign scientists and cosmonauts. In the name of the forum participants, USSR Academy of Sciences President G. I. Marchuk greeted the crew with the 30th anniversary of the space era.

On 24 October at 16 hr. 9 min. 16 sec., Yuriy Romanenko exceeded the world record for the continuous time spent in space flight by 10%, and became the official world record holder. Nevertheless, his flight still continued, and therefore this new achievement will greatly exceed the former one. The International Aviation Federation also records the total space flight time of one person as a record. Prior to the current flight of Yuriy Romanenko, the official record holder was Valeriy Ryumin, with a result of 361 days, 21 hrs. 33 min. 00 sec. over three space flights. And although Leonid Kizim and Vladimir Solov'yev had flown more (respectively 374 days 18 hrs. 19 min. 38 sec. and 361 days, 22 hrs. 53 min. 56 sec), they did not have the required 10% to break the official world record.

On 3 November at 11 hrs. 52 min. 33 sec., Yuriy Romanenko exceeded the achievement of Leonid Kizim, and on 26 November at 20 hrs. 00 min. 3 sec. he became the new record holder for total flight time in space flight. Thus, in all articles he took first place among the long-time space fliers. Of course, it is always nice to break a record. However, cosmonauts, although they do enjoy sports, nevertheless do not distinguish themselves in their work with sports results, but primarily with specific endeavors in the interests of science and the national economy. And in this sense the "Taymirs" performed unique work /37 on an extensive program of research, and primarily with the application of the "Kvant" space module.

The return to Earth lie ahead of them. Everyone who has been in space affirms that the most emotional part of the space experience is the descent. Launch into orbit and docking occur more calmly. At the section of launch into orbit everything takes place quickly, but during descent there is time to think, to examine one's feelings. Everything goes according to the program. The ship's living quarters, no longer needed, separate away. The running engine has worked for the given time, diminishing the orbital speed. The equipment-instrument compartment has separated away.

The crew begins to feel an overload. This means they have entered the dense layers of the atmosphere. Behind the portholes are red flames. This is the lining of the descent craft burning off. During this time you can feel heaviness pressing down on you, and even your voice faces from the overload. But the smart machine seems to feel how hard it is for the people, and enters a more gently sloping trajectory. This is the descent control system engines switching on, and suddenly it is easier to breathe. Then the "cobblestones" begin. The

The stage of descent before the parachute opens is accompanied by shaking, similar to driving on a cobblestone road.

The descent craft hangs over Earth under a white and orange dome of the main parachute. The search helicopters circle nearby, descending together with the descent craft. And then the soft landing engines raise a cloud of dust, and the descent craft is on Earth. The sporting commissars record the exact time of the landing to the second, cameras click, movie cameras whir, the crew gives its first interview, and the physicians perform their first medical examination. Everyone has his own tasks.

The first steps on Earth are taken in a state which is difficult to compare with anything. One's head spins from the entrancing smell of the steppes. There, on the orbital station, you breathe conditioned air, and it seems quite bearable, but only until you land. No artificial lighting can compare with the joy which the sun's rays give with their life-giving heat, and earth food is still much better than any space delicacies...

INTERNATIONAL COOPERATION OF THE USSR IN SPACE

S. A. Nikitin

International cooperation by the Soviet Union in the study and application /38 of space for peaceful purposes in 1987 was successfully developed with 9 socialist countries (PRB, HPR, NRV, GDR, Republic of Cuba, MPR, PPR, SRR, and CzSSR) within the framework of the multilateral program "Interkosmos" (Interspace), and on a bilateral basis--with Austria, Great Britain, India, France, the FRG, USA, Sweden and other countries, as well as with the European Space Agency. According to the "Interkosmos" program, joint work was conducted in the sphere of space physics, including space materials science, in the sphere of space meteorology, communications, space biology and medicine, as well as long-range probes of Earth for purposes of studying its natural resources. Joint operations in space on a bilateral basis with the above-named countries encompassed practically all the basic spheres of cosmonautics.

In 1987 the main events in USSR international cooperation in space became: the launch of the international astrophysical observatory "Kvant", the flight of the Soviet-Syrian international crew, international experiments performed on the "Mir" orbital complex by the members of the main expedition--cosmonauts Yu. V. Romanenko and A. I. Laveykin, the flight of the regular international biosatellite "Kosmos". This year, the anniversary of the "Interkosmos" program was celebrated, and new agreements were signed regarding cooperation in space between the USSR and USA, the USSR and Great Britain. On 2-4 October 1987 the international forum on "Cooperation in space in the name of peace on Earth" was held in Moscow. Around 900 Soviet and foreign scientists and specialists in the field of space research participated in this forum.

The Center for Cosmonaut Training imeni Yu. A. Gagarin, located near Moscow, is training new international space crews. The second Soviet-Bulgarian manned flight (cosmonaut candidates from the PRB--A. Aleksandrov and K. Stoyanov) is planned for 1988 on the Soviet spacecraft and orbital station. The French cosmonaut G.-L. Kretien and cosmonaut candidate M. Tonini are also being trained in Zvezdnoy gorodok (Star City) for the second Soviet-French manned flight. One of them will be a member of the Soviet-French crew which in 1988 will perform a flight on the Soviet spacecraft and orbital station. The planned duration of this flight is around 30 days, and the French cosmonaut will go out into open space.

An agreement has been reached on conducting a Soviet-Afghan space flight in the first half of 1989. During the negotiations of USSR Council of Ministers Chairman N. I. Ryzhkov with the Federal Chancellor of Austria F. Vranitskiy it was reported that with consideration for the desire expressed by the Austrians, the Soviet Union has reviewed the question of the possibility of performing a joint flight of Soviet and Austrian cosmonauts. The flight of this international crew may be performed in the early 90's (with consideration of time for training operations).

On 31 March 1987 USSR Minister of Foreign Affairs E. A. Shevardnadze and Great Britain's Minister of Foreign Affairs G. Howe signed the "Agreement between the government of the Union of Soviet Socialist Republics and the government of the United Kingdom of Great Britain and Northern Ireland on cooperation in the sphere of research, study and application of space for peaceful purposes". This agreement was signed in Moscow. Cooperation within the framework of this Agreement will encompass such scientific spheres of space research as solar-earth physics, planetology, astrophysics of higher energies, including astronomical research in the x-ray and far ultraviolet ranges, submillimetric and infrared astronomy, radio astronomy, materials science, space biology and medicine, as well as other spheres which from time to time may be mutually coordinated between the countries.

Joint measures within the framework of this agreement, which was signed for a period of 10 years, but which subsequently remains in force if one of the parties does not notify the other about the cessation of effect of the Agreement, will be implemented in the following forms: exchange of delegations of scientists /40
and other specialists and participation in joint research and design works defined by scientific and other research organizations; exchange of experience, scientific information and literature; cooperation in implementing joint projects on the design, development and launch of apparatus; conducting joint symposia and other measures on joint coordination of the parties.

On 15 April 1987 USSR Minister of Foreign Affairs E. A. Shevardnadze and USA Secretary of State G. Schultz signed the "Agreement of the USSR and USA on cooperation in the study and application of space for peaceful purposes". The agreement was signed for a period of 5 years and may be prolonged for other 5-year periods by means of exchange of notes between the parties.

This Agreement provides for cooperation in such spheres of space science as the study of the Solar System, space astronomy and astrophysics, science of the Earth, physics of solar-earth ties and space biology and medicine. Co-operation in these fields will be conducted by means of mutual exchange of scientific information and delegations, organization of meetings of scientists and specialists, exchange of scientific apparatus and mutual coordination in other forms. The practical realization of joint work will be implemented through mixed work groups formed in each of the above-listed fields.

The mixed work groups will begin their work with projects, whose list has been coordinated by the parties and presented in the appendix to the agreement. This list includes the coordination of the projects "Phobos", "Vesta", and "Mars observer", and the exchange of scientific data on their results; joint research on the identification of the most promising places for landing on Mars; exchange of scientific data on the study of the surface of Venus; in the sphere of radio astronomy, space gamma-, x-ray and submillimetric astronomy; coordination of observation on projects for the study of physics of solar-earth ties and exchange of corresponding scientific data; coordination of work on studying the global changes of the environment; cooperation on a program of biosatellites of the "Kosmos" series; exchange of biomedical data on manned flights by the USSR and USA.

The anniversary of the "Interkosmos" program. In April 1987 the "Interkosmos" program was 20 years old. This program was adopted in April of 1967 in Moscow at a meeting of experts on questions of cooperation in space, representing 9 socialist countries: PRB, HPR, GDR, Republic of Cuba, MPR, PPR, SRR, USSR and CzSSR. On 13 July 1976 the representatives of the governments of these 9 socialist states--participants in the "Interkosmos" program--signed the "Agreement on cooperation in the field of study and application of space for peaceful purposes". This Agreement strengthened the accumulated experience of joint work in space and became a factor in its further development. In May of 1979 the Socialist Republic of Vietnam joined in the Agreement, becoming the tenth country to participate in the "Interkosmos" program.

. The adoption of the "Interkosmos" program signified a qualitatively new stage in the development of cooperation of the socialist countries in space research--the transition from ground-based observations which were performed according to coordinated programs since 1957, to closer and more effective forms of cooperation. In the 20 years of the realization of the program, 23 "Interkosmos" satellites were launched, 11 high-altitude research rockets of the "Vertikal" type, and a large number of meteorological rockets. On board a number of the spacecraft launched by the USSR in accordance with the national program (satellites "Kosmos", "Meteor", "Prognoz", unmanned interplanetary stations "Venera", "Vega", spacecraft "Soyuz", orbital stations "Salyut" and "Mir"), instruments were installed which were created by specialists from the socialist countries within the framework of the "Interkosmos" program.

An important step in the development of the "Interkosmos" program became the flights of the 9 international crews (March 1978-May 1981) on the Soviet "Soyua" spacecraft and the orbital station "Salyut-6". These crews were comprised of cosmonauts--citizens of all the socialist countries participating in the agreement. The primary task of the international crews was to conduct scientific research and experiments which had been prepared jointly by scientists and specialists of the socialist countries. To solve the presented research problems, over 30 instruments and devices were specially designed and manufactured. /42
With the aid of these the international crews performed over 150 experiments in the field of space biology and medicine, the study of the Earth surface and its atmosphere, and in the field of astrophysics and the study of the physical properties of space and space materials science.

The last years in the development of the "Interkosmos" program are characterized by the beginning of a new stage, whose basic peculiarity is the implementation of wide-scale multi-purpose scientific-technical projects. Their realization demands the attraction of scientific organizations of many countries to the joint efforts, i.e., it leads to the need for complex cooperation in scientific ties. Such projects are becoming predominant in the "Interkosmos" program, and their realization is being aided by scientific organizations not only of the socialist, but also of the capitalist countries. The brightest and freshest examples of such broad-scale joint work of multi-purpose directionality are the projects "Venus--Halley's Comet" and "Phobos".

In the course of 20-year joint work on the "Interkosmos" program, results have been obtained which represent a significant contribution to the various sections of the science of space and to the applied directions of cosmonautics in the interests of the national economy. These results have been systematically reported at sessions of COSPAR (Committee on Space Research), IAF (International

Astronautical Federation) Congresses, and other international symposia and conferences.

In the next few years, in accordance with the jointly developed long-range plans for cooperation within the framework of the "Interkosmos" program, there will be developments in all five of the above-mentioned fields, of whose projects we will speak somewhat later.

The astrophysical module "Kvant". On 31 March 1987 in the Soviet Union, with the aid of the "Proton" booster rocket, a specialized astrophysical module "Kvant" was placed into orbit around the earth. It was intended for operation in combination with the "Mir" orbital complex. Docking with the complex was set for 5 April.

The first effort to dock the "Kvant" with the manned orbital complex turned out to be unsuccessful. Up to a distance of 200m the approach of both space- /43
craft went as outlined in the program, but at the final stage, due to shut-off of the guidance system of the astrophysical module the approach of the craft was stopped. On 9 April the docking of the "Kvant" with the orbital complex was repeated. The mutual search, approach, docking and juncture were performed with the aid of on-board automatics of the spacecraft. The "Kvant" was docked to the station at 4 hrs. 36 min Moscow time on the side of the instrument compartment. After mechanical connection of the juncture assemblies, the pulling together of the spacecraft was begun. Analysis of the incoming information showed that the pulling together of the "Kvant" module with the "Mir" station was not fully completed.

In order to achieve full connection, on the night of 12 April 1987 cosmonauts Yu. V. Romanenko and A. I. Laveykin went out into open space and spent 3 hrs. 40 minutes there. Before inspection, the spacecraft were separated for the maximally possible distance by means of moving out the arm of the connection assembly of the module and the station. This inspection showed that their juncture was being hindered by some foreign object which had gotten between them. The cosmonauts removed it, after which the spacecraft were joined together. This process was performed upon commands from Earth and was visually controlled by the crew. As a result, a manned space complex "Mir"--"Kvant"--"Soyuz TM-2" was formed in orbit around the Earth, with overall mass of 51 tons and length of 35 m.

The astrophysical module "Kvant" represents a specialized space apparatus intended for performing a broad range of studies in the field of extra-atmospheric astronomy and solution of a number of other scientific and national economic problems. After the module was placed into orbit around the earth with the aid of the "Proton" booster rocket, its maneuvering in orbit, approach and docking with the "Mir" station were achieved by a functional service unit equipped with an engine installation. The initial mass of the module with the service unit comprised 20.6 tons. The separation of the service block of the "Kvant" module was performed after docking with the station. This occurred on 13 April at 0 hrs. 18 min, and this freed a second docking unit on the "Kvant", which was located on the side of the unit which had separated away, and was intended for /44
receiving transport craft.

The basic characteristics of the "Kvant" astrophysical module are as follows The mass (without the service block, i.e., within the make-up of the orbital complex) is 11 tons, the length is 5.8 m, the maximal diameter is 4.15 m, the payload mass is 4.1 tons, including the mass of the scientific instruments which is 1.5 tons and the weight of equipment for expanding the capacities of the "Mir" station, 2.6 tons.

Structurally, the module consists of a laboratory compartment with passage chamber (hermetic construction) and a non-hermetic compartment for scientific instruments. All the conditions for normal work of the crew have been created on the "Kvant". The volume of the air-tight laboratory compartment comprises 40 m^3, there is a control point for monitoring the operation of the systems and instruments. The controls are convenient to use. The life support system creates the same conditions as in the other compartments of the "Mir" complex.

The laboratory compartment with passage chamber is intended for the installation of the main portion of the service, experimental and part of the scientific equipment of the module, as well as for active and passive docking assemblies. For placing instruments and assemblies inside the laboratory compartment, a horizontal system of arrangement is adopted with isolation of the central living zone, which is separated from the instrument zone by interior decorative panels. There are two portholes in the laboratory compartment. The first is 430 mm and is intended for the installation of an optic sighter. The second, 228 mm in diameter, is equipped with a visual astro-orientation instrument. Two other portholes 80mm in diameter are located in the passageway chamber. They are intended for visual observations. One of them is oriented along the axis of the module, and the other--at an angle to it.

Located in the passage chamber is the sluice gate for servicing the ultraviolet "Glazar" telescope (loading and unloading cassettes). Also installed here is the control panel for the telescope. In the laboratory compartment and passage chamber there are five daylight illuminators which create light of no less than 100 Lx over the entire volume of the module.

All the panels for control and guidance of the systems operations, as well as the visual gauges and control organs are placed in the crew's work zone and located on the interior panels or on the central control post. Inside the /45 laboratory compartment are instruments and aggregates for the following systems: control of the on-board complex; control of movement; approach and docking; on-board measurements; provision of gas composition; provision of thermal regimen; docking and internal passage; hermetic (air-tight) check. In the laboratory compartment there are also the instruments for the integrated radiotechnical system, the system of telephone-telegraph communications, the television apparatus, and individual instruments and aggregates of scientific and experimental function.

Without going into detail about the operation of the above-listed systems and equipment, let us deal more closely only with the system of movement control, since its functioning is principally important for performing scientific research and experiments. The system of movement control is intended for providing approach of the module with the station and for focusing the scientific apparatus on the selected celestial objects and zones of the earth's surface. This system includes sensitive elements (gauges), blocks of electronic indicators, an on-board computer complex, and executive organs. The gyroscopic power stabilizers (Gyrodynes) installed on the module are used as the executive organs in the system of movement control (guidance).

Why did the designers settle on such a system of orientation and stabilization control?

In order to obtain the greatest scientific return from the orbital complex, it was necessary to significantly, by more than an order, increase the accuracy of orientation of the complex. For effective application of the scientific apparatus it is necessary to focus the telescopes on the studied object with an accuracy of no less than several angular minutes. At the same time, it was necessary to sharply increase the duration of the orientation flight. Practically during the entire time of its existence in orbit, the "Mir" complex had to be in oriented flight, if we consider the fact that the system of movement guidance also had to turn the complex in such a way that the panels of the solar batteries are properly illuminated.

All the above-listed problems were solved by using the principles of force gyroscopy. For comparison, let us recall the system of guidance around the /46
center of the mass in the "Salyut" orbital station. Its executive organs, which ensured turns and maintaining the necessary orientation, required constant fuel expenditures. Here, naturally, the more precise the orientation, the greater these expenditures became. In order to replentish the fuel reserves, the "Progress" cargo ships were used, but even with delivery of fuel by 6-8 cargo ships per year, the "Salyut" could fly in oriented position no more than 5-10% of the overall time spent in orbit.

This is why the creators of the system of movement guidance around the center of the mass for the "Mir" complex chose a different route and developed a system of electromechanical executive organs which use energy only from the sollar batteries and storage batteries. This system makes it possible to perform orientation of the "Mir" complex and its stabilization in space without the expenditure of fuel from the engine installation The force gyroscopes (gyrodynes on magnetic suspension) used in this system have a complicated electron-mechanical complex as their executive organs, which include two-stage force gyroscopes (6 units) with electrical drive, and electronics units. Here the rotor of the force gyroscope rotates in a magnetic field of the guidance electro-magnets. To reduce the friction, the rapidly turning rotor is encased in a hermetic casing, which is joined with open space.

The results of test runs of the gyrodyne system of movement guidance of the complex with precision of orientation computed by 1^{1}, present new possibilities for space researchers.

The scientific instrument compartment is intended for the placement of scientific apparatus in the module, as well as for instruments and aggregates which require installation in a non-hermetic volume of the module.

The following components comprise the scientific equipment of the "Kvant" module.

1. The International Orbital Observatory "Rentgen", created by the scientists of the Soviet Union, Great Britain, the Netherlands, the FRG, and the European Space Agency. The observatory represents a specialized set of instruments intended for research in the field of x-ray astronomy and study of x-ray /47

spectra in the energy range of 2-800 keV. This complex includes:

a telescope-spectrometer with harsh x-ray radiation (20-800 keV), "Pul'sar X-1: with a field of vision of 3^{o} x 3^{o} developed by the USSR Academy of Sciences Institute for Space Research, and a detector of gamma-flashes of cosmic origin with semi-spherical field of vision;

a scintillation telescope-spectrometer for high energies (15-200 keV) "Gekse", with field of vision of 1.7^{o} x 1.7^{o} developed by the Institute of Non-Atmospheric Physics of the Max Plank Society (FRG) and by Tubingen University (FRG);

a TTM telescope with shade (coding) mask (2-30 keV) with field of vision of 7^{o} x 7^{o} developed by the Utrekht Laboratory of Space Research (Netherlands) and Birmingham University (Great Britain), intended for building images in the x-ray spectral range;

a gas scintillation proportional spectrometer "Siren'-2" (2-100 keV) with field of vision of 3^{o}x 3^{o} developed by the European Space Agency.

Research and experiments with the aid of the "Rentgen" orbital observatory are conducted in the regimen of inertial orientation of the orbital complex on gyrodynes with more exact orientation by the crew with the aid of an astro-orientation instrument. Information is transmitted to Earth over telemetric channels.

2. An ultraviolet space telescope "Glazar", developed by scientists at the Byurakansk Astrophysical Observatory (USSR) with the participation of specialists from Switzerland, and intended for obtaining photographs of the sky within a wavelength range of 120-130 nm. The telescope may operate in the manual as well as in the automatic modes. It is equipped with an automatic search, monitoring and precision stabilization system, realized with the aid of stellar indicators and special electronic devices. The photographs obtained by the "Glazar" telescope are returned to Earth on the "Soyuz TM" ships.

3. Automated electrophoretic installation "Svetlana", developed by specialists of the Soviet Union and intended for performing biotechnological experiments for the purpose of working out methods of electrophoretic purification of /48
biologically active substances under conditions of microgravitation, and for obtaining experimental batches of anti-viral preparations and fractions of highly active microorganisms--producents for use in the national economy. The preparations are returned to Earth in the "Soyuz TM" ships.

In accordance with the International Program of Astrophysical Research, the first experiment with the aid of the "Rentgen" orbital observatory was performed by the cosmonauts on 9 June 1987. The object of observation was the Supernova in the Great Magellan Cloud, which flared in February of 1987. Later, in June-September of 1987, a series of observation sessions were performed on the x-ray sources in the constellations of Cygnus, Centaurus, and Hercules, as well as the Supernova in the Great Magellan Cloud. Also performed were measurements necessary for the compilation of x-ray charts of individual parts of the sky. On 13 August 1987 the instruments of the "Rentgen" observatory registered a possible flare of gamma-radiation of cosmic origin.

At the end of June, studies were begun with the aid of the "Glazar" ultraviolet telescope, in which Swiss scientists participated together with Soviet scientists. These experiments yielded information about the short-wave radiation of galaxies. The objects of study were the ultraviolet cosmic sources in the constellations of Puppis , Grus, Pavo , Andromeda, Piscis Austrinus, and in the regions near the stars Alpha Pávo and Alpha Eridanus

Research is continuing. Soviet and foreign scientists give a high evaluation to the information which has already been obtained with the aid of the apparatus on the "Kvant" astrophysical module.

<u>The "Kosmos-1887" Biosatellite</u>. On 29 September 1987 the Soviet Union launched the "Kosmos-18" biosatellite.

On board the "Kosmos-1887"--the eighth* specialized biosatellite intended /49 for continuing research on the effect of space flight factors on living organisms, were scientific-experimental systems with various biological objects, as well as apparatus for radiation-physics studies.

---

* Since 1973 the Soviet Union has launched seven specialized biosatellites--"Kosmos-605" (1973), "Kosmos-690" (1974), "Kosmos-782" (1975), "Kosmos-936" (1977), "Kosmos-1129" (1979), "Kosmos-1514" (1983), "Kosmos-1667" (1985), with the research, beginning with the "Kosmos-782" satellite, being conducted in the framework of international cooperation.

The duration of the flight of the biosatellite "Kosmos-1887" was planned for 14 days, which will make it possible to study the physiological reactions of an organism in the initial (1-7 days), as well as in the transitional (8-14 days) period of adaptation to weightlessness.

During the flight of the biosatellite "Kosmos-1887", research and experiments are conducted on monkeys, on rats, on gravitational biology, as well as radio-biological and radiation-physics studies.

The basic object of study on the "Kosmos-18", as in the two previous bio-satellites, are two monkeys--male rhesus-macaques aged 4 years and weighing around 4 kg each. The monkeys on board the biosatellite are kept in special capsules.

In the experiments on the monkeys, the basic attention is given to studies of the vestibular apparatus, the motor system, the central nervous system, and the biorhythms. Before and after the flight, in addition to the experiments listed above, studies of the clinical state of the monkeys are also performed, studies of the gas- and energy exchange, immunity, water-salt metabolism, structure and biochemistry of the muscles and bone tissue.

In a special unit, whose construction is analogous to the units used in the flights of the biosatellites "Kosmos-1514" and "Kosmos-1667", male rats of the Vistar strain are kept, supplied by the Institute of Experimental Endocrinology of the CzSSR Slovak Academy of Sciences (Bratislava). The age of the rats at the beginning of the flight comprised 2 months, and their weight was around 300g each. The experiments on rats pursue the following goals: the study of structural and metabolic changes occurring in the organism in the transitional period of adaptation to weightlessness; evaluation of the role of various regulatory systems in mechanisms of adaptation to weightlessness; study of the dynamics of adaptation to weightlessness of the individual functional systems and the organism as a whole on the basis of comparison of results obtained in this and in preceding flight experiments on rats.

A specific task of studies on gravitation biology consists of seeking the /50
biological effects of weightlessness and identifying the biological mechanisms of adaptation to the altered force of gravity. Here the primary attention is given to the cell level of organization of living matter. The program includes 12 experiments with various biological objects: single-celled animals, higher plants, insects, fish and amphibians.

Two experiments on the "Kosmos-1887"are being performed by young biologists from the Central Palace of Pioneers. In the first, the planaria (flatworm) is used to study the process of regeneration of various fragments of the dissected body. Another experiment consists of two parts. The first part of the experiment--a culture of coli bacillus infected with moderate bacteriophage, is used to study the induction of transition from the inactive to the active state under the effect of space flight factors. In the second part of the experiment, a streptococcus culture is used to study the synthysis of the antibiotic nisin under conditions of weightlessness.

In the field of radiobiology, studies are being conducted on the "Kosmos-1887" satellite on the effect of heavy charged particles of galactic cosmic rays on the kinetics of cell reproduction and cell ultrastructure; on the cell populations of mechanisms of restoration on cells of higher plants; on determining the possibility of non-biological synthesis.

Together with Soviet scientists, specialists from the HPR, GDR, PPR, SRR, CzSSR, USA, France, and the European Space Agency are participating in the scientific program of the "Kosmos-1887" biosatellite.

On 12 October 1987 the descent craft of the "Kosmos-1887" biosatellite landed in an unplanned region (city of Mirnyy, Yakut ASSR). The monkeys Drema and Yerosha and other biological objects fared well through the landing and the frozen Yakut taiga, and are in good health.

New international space projects. Within the framework of the international cooperation of the Soviet Union in space, work is currently being performed on several new projects.

The preparations for the project "Phobos" have entered the final stages. This project provides for the launch of two Soviet unmanned interplanetary stations (UIS) to Mars. The expedition will bear a multi-purpose character. /51
Its intentions are the study of the interplanetary reaches of space, the Sun, the planet Mars and the Mars satellite--Phobos. Work is being conducted in the framework of broad international cooperation: the scientific apparatus for the UIS is being developed by scientists and specialists from the Soviet Union, Bulgaria, Hungary, the GDR, Poland, Czechoslovakia, Austria, Finland, France, the FRG, Switzerland, Sweden, and the European Space Agency. The UIS for the project "Phobos" will launch from the cosmodrome at Baykonur in July of 1988. The flight to Mars will take around 200 days.

Along the trajectories of the flight to Mars, experiments will be conducted on the study of the Sun and interplanetary space. The studies of the Sun, the solar corona and the processes of solar activity have been conducted for a long time and in many countries. Major fundamental results have been obtained in this direction. However, the conducted research has generally been performed from Earth and from orbits around the Earth. In this case, the research possibilities are greatly expanded, since the study of the Sun is planned to be done at rather great angles (angle Earth--Sun--UIS). After the launch of the UIS, as they go farther away from Earth this angle will change from 0 to 40° (upon reaching Mars), and by the end of the expedition to 180°. During observations of the Sun simultaneously from on board the IUS, from Earth, and from satellites around the Earth, a unique possibility will be presented for determining the spatial structure of the chromosphere and the corona, as well as for observing the processes which cannot be seen from Earth at that time.

To study the Sun, a so-called solar complex of scientific apparatus is being installed on board the UIS. It is intended for analyzing the optical, ultraviolet, x-ray and gamma radiation. It is expected that we will obtain images of the Sun and its corona in x-rays, will regularly record the intensity of the ultraviolet radiation of the Sun, will perform a study of the gamma-flashes of solar and cosmic origin. The experiment on studying solar oscillations associated with clarification of the internal structure of the Sun and the processes taking place in its nether regions--is of great interest. As we know, solar pulsations were discovered by scientists at the USSR Academy of Sciences /52
Crimean Astrophysical Observatory. Research in this direction promises interesting results dealing with the structure and dynamics of the make-up of the Sun, and the conditions of conducting the "Phobos" expedition are quite convenient for such measurements.

Along the flight trajectories to Mars, studies will also be performed with the aid of the plasma complex instruments.

Upon reaching Mars, the UIS will first go into elliptical orbits around the planet. These will later be transformed into circular orbits. From the circular equatorial "orbit of observation", autonomous navigational measurements of the parameters of motion of the UIS relative to Phobos will be conducted. At the same time, television images of Phobos will be transmitted to Earth for clarifying its form and the details of its relief. About a month is planned for this stage of the expedition. After processing of the information by ground-based computers, upon commands from Earth, a maneuver of the transition of the UIS to a circular areocentric orbit synchronous with Phobos is planned. The next 2 months will be devoted to getting and processing information which will make it possible to "bring up" the UIS to a distance of within 35km of the studied object--Phobos. Beginning with this distance, already at the command of on-board instruments, further approach of the UIS to Phobos is planned.

At the "hovering" altitude (around 50m) for a period of 15 minutes, comprehensive studies of phobos are planned: television photography, radiological sounding of the internal structure of the Mars satellite, laser and ion-beam radiation of its surface with vaporization of substance probes and subsequent study of the chemical and physical properties of the "vaporized" substance with the aid of instruments found on board the UIS. At the end of the "hovering" period, two types of landing probes will separate away from the IUS, and will conduct research directly on the surface of Phobos. After this, the IUS will change over to the given areocentric orbits to continue the scientific program of the expedition: long-range studies of Mars and its atmosphere, the study of the space around Mars and continued study of the Sun.

The overall duration of the expedition is almost 1.5 years (460 days).

The central part of the scientific program of the expedition is the study of Phobos. The nature and origin of the Martian satellites is still largely a /53 matter of conjecture. Phobos has the form of a potato with dimensions of about 30 x 20 km. There are many hypotheses which try to explain how a Mars satellite could have ended up in an areocentric orbit. According to one of them, Phobos and Daimos may be related to class C asteroids captured by Mars.

Phobos has a very dark (albedo around 5%) uneven surface, dotted with numerous craters of impact origin. Totally unexpected formations were discovered on Phobos--many practically straight and almost parallel furrows 200-300m wide and 20-30m deep. Almost all of them began at the largest crater Stykni, which is 10km in diameter. i.e., over a third of the diameter of Phobos itself. The mass of Phobos is about $1.5 \cdot 10^{-3}$ times the mass of Mars, its average density is around $2g/cm^3$. Thus, Phobos cannot consist of dense soils refused by volcanic processes, of which the core and mantle of planets of the Earth group are comprised. Spectral observations of changes in the reflective capacity of Phobos showed that they (these changes) have the same character as carbonaceous chondrite--a well known type of meteorite.

The integrated program for the study of Phobos provides for the study of the surface of this Mars satellite (chemical and mineralogical composition, mapping with high resolution capacity, physical properties and radiophysical characteristics), its internal structure (seismology, large-scale structures) and parameters of orbital movement (free and forced librations, age deceleration). The studies of Phobos will be conducted in the period when the IUS approaches its surface to several tens of meters and performs a slow-speed fly-over.

One of the main elements in studying the Mars satellite will be the active long-distance probe of the surface. In the experiment "Lima", a laser beam with energy of approximately 0.5 J, focused on the surface of Phobos to a diameter of 1-2mm within a very short time (10 nsec) will cause explosive vaporization and ionization of the substance. The formed ions will be dispersed, and part /54
of them will get into a special instrument--a reflectron, mounted on the IUS. Here the mass composition of the particles will be analyzed by the time of their flight from the surface of Phobos to the "trap" of the instrument.

In the experiment "Dion" an ion gun will emit crypton ions accelerated to energies of 2-3 eV. These ions will break secondary ions out of the substance of the surface layer of Phobos. These will then be recorded on board the IUS by a mass spectrometer. The experiment will make it possible to study the composition of the surface layer of the Mars satellite and to determine in it elements which have been implanted by solar wind. During the time of the IUS fly-by over Phobos, the methods used in the experiments "Lima" and "Dion" will study the soil at about 100 points.

The surface relief, the subsurface structure and the electrophysical characteristics of the Phobos soil will be studied in the experiment "Soil" (Grunt" by the method of radio sounding.

A television system will provide photography in three spectral ranges, and scientists hope to obtain synthesized (color) images on which the details of the surface slightly larger than 6 cm will be discernible. At the same time, spectrophotometric analysis of the photographed sections will be performed in 14 zones with resolution of 50 nm. With the aid of a movable mirror, the focus of the television system may be directed not only at Phobos, but also at Mars, as well as at the brightest stars, which is important for solving the problems of navigation.

Finally, the methods of gamma- and infrared spectroscopy will be used to study Phobos. This will make it possible to judge the thermophysical and reflective properties of the surface of the Mars satellite and its mineralogical composition. Information will also be obtained on the basic soil-forming elements--iron, silicon, aluminum, calcium, magnesium and others, as well as natural radioactive elements--uranium, thorium, and potassium.

An important role in the study of Phobos is given to the landing probes. One of the variants of a landing probe has been named the long-life autonomous station (LAS). The LAS separates from the IUS when the latter is at a distance of several tens of meters from the surface of Phobos. After separation, the /55
LAS will begin to slowly "fall" to the surface of the Martian satellite. Here the relative speed of approach of the LAS to Phobos will comprise several meters per second. Oriented touching of the surface is planned, for which the LAS, after separation, is given a rotation around its longitudinal axis. After touching, the LAS secures itself on the surface.

The task of the LAS is to conduct scientific experiments on Phobos which require long-term measurements. Among these experiments are studies on celestial mechanics performed with the aid of the LAS radio system and ground-based receiving-transmitting antennae (basic information here--measurement of distance; anticipated accuracy 5m); the study of librations of Phobos, achieved by means of autonomous measurements of the angular position of the Sun with an optical indicator and radio interference measurements using signals from two LAS transmitters removed from each other on the surface; the registration of seismic noises caused by the gravitational field of mars, falling of meteorites, thermal expansion during transition from night to day. These will be recorded by a seismometer.

Another group of experiments on the LAS is intended for studying the elementary composition of the surface layer, its structure and physico-mechanical characteristics. The basic volume of information on the elemental composition will be obtained from on-board the UIS by long-range methods. Direct measurements with the aid of the LAS are necessary for calibration and to facilitate the interpretation of the data from long-range measurements. The duration of work of the LAS on the surface of Phobos will be about a year.

One other variant of the landing probe is being considered--the mobile (or more precisely, jumping) variant, moving over the surface of Phobos. After

landing and settling of the apparatus on the surface, the probe is brought to operational position with the aid of the "feelers" of the orientation device. Then scientific measurements are performed and the information is transmitted over radio channel to Earth. The next cycle of measurements is performed after the probe has jumped with the aid of a device which enables it to push off for a distance of up to 20 m. Again, after settling the probe is ready to repeat the cycle of work. The number of cycles may be up to 10. The scientific apparatus of such a probe includes a device for measuring accelerations upon /56
impacting with the surface, an x-ray-fluorescent spectrometer for studying the chemical composition of the soil surface layer, a penetrometer for studying the physico-mechanical properties of the soil, and a magnetometer for measuring the magnetic fields.

Thus, with the aid of landing probes, for the first time in the history of space research we plan to obtain through direct measurements data about the structure, chemical and mineralogical compositions of the surface of Phobos.

Let us say a few words about the study of Mars and its vicinity using instruments which are part of the planetary complex of scientific apparatus. In the period of orbital flight of the UTS around Mars, its surface will be studied by methods of long-range probe in the visible, infrared and gamma-ranges of the spectrum. We plan to obtain a temperature map of the Mars surface, to study the diurnal and seasonal dynamics of its temperature regime, to measure the thermal inertia of the Martian soil, and to implement a search for sections of emission of endogenous heat and regions of permanent frost. Data will be obtained on the mineralogical composition of the Mars surface. The method of gamma-spectroscopy will be used to determine the content of the basic soil-forming elements (oxygen, magnesium, aluminum, silicon, calcium, iron) and the natural radioactive elements (uranium, thorium, potassium). These data will allow us to judge as to the character of the soils, their chemical composition, and the degree of differentiation of the soils in the process of their formation.

A series of experiments on studying the atmosphere and ionosphere of Mars is also planned.

Thus, in July of 1988 two UTS will be launched for Mars, each of which will be equipped with over 30 scientific instruments. With their help, we plan to conduct a broad program of unique integrated research on several objects of the Solar System. The results of these studies will allow us to move ahead in understanding one of the fundamental problems of natural science--the problem of the origin of the Solar System, the planets and their satellites.

Geophysicists in the socialist countries have high hopes for the projects "Aktivnyy" (active) and "Apex".

The primary scientific task of the "Aktivnyy" project consists of integrated studies of the processes of dispersion of electromagnetic waves of the ULF (ultra- /57 low frequency) range in the ionosphere and the magnetosphere of the Earth. The characteristic peculiarities of this project are: the application of an autonomous subsatellite with correcting engine installation, a branched recording network of ground-based measurement points, original recording apparatus on the main spacecraft, with 20m-long antenna which will open in space, and a sophisticated analyzing complex, etc. The satellite on the "Aktivnyy" project is planned for launch in 1988.

The basic scientific goals of the "Apex" project (active plasma experiment) consist of initiating and simulating geophysical phenomena in the plasma around the earth by means of injecting beams of charged particles into the plasma and studying the fundamental processes in the plasma under conditions which are inaccessible for laboratory studies. As in the previous project, the main satellite for the "Apex" project will carry an autonomous maneuvering subsatellite. The launch of the main satellite for the "Apex" project is planned for 1989.

Scientists and specialists from practically all countries participating in the "Interkosmos" program are working on the "Aktivnyy" and "Apex" projects.

The project "Interbol" also evokes great interest. The goal of this project (the beginning of its realization is planned for 1990) is to continue on a qualitatively new level the study of solar-earth communications, specifically the mechanisms of transporting the energy of solar wind to the Earth's magnetosphere. Thanks to the use of a single system comprised of four spacecraft (two "Progress" type satellites and to small autonomous subsatellites which will separate away from them), the measurements will allow us to study the interrelations of phenomena in the key regions of the magnetosphere. Scientists and specialists from the USSR, the PRB, HPR, GDR, Republic of Cuba, PPR, SRR, CzSSR, France, Sweden and the European Space Agency are participating in the preparation of experiments and in creation of the apparatus for the "Interbol" project.

We must stress the principle peculiarity of the "Aktivnyy", "Apex" and "Interbol" projects. The projects undertake major scientific goals, and at the same time their results will have great practical value.

AN IMPORTANT STEP IN JAPAN'S SPACE PROGRAM

D. Yu. Gol'dovskiy

Over a year ago, on 13 August 1986, Japan launched two artificial earth satellites (AES) into orbit. These were called "Fuji" (after Mt. Fujiyama) and "Adzisay" ("Hortensia"). The first of these, weighing 50 kg, is intended for communications between ham radio operators. The purpose of the second (weighing 680 kg) was to serve as a reflector for ground-based lasers in performing geodesic measurements. The creation of these two AES was not such an extraordinary scientific-technical achievement for Japan. So why did the launch on 13 August 1986 attract particular attention not only in Japan, but abroad?

The fact is that this launch first utilized the Japanese booster rocket (BR) "Eych-1" (in the two-stage variant), which signified a new and significant step in Japan's space program. A year later, on 27 August 1987, the second launch of the "Eych-1" rocket was performed (already in a three-stage variant). It placed the experimental navigational AES "Kiku-5" weighing 550 kg into geostationary orbit.

Japan launched its first AES with domestic-made solid fuel BR. Similar solid fuel, though slightly modified BR continue to be used even today. Their capacity is not great, although it is sufficient for placing small AES and even unmanned interplanetary stations (UIS) such as "Susey" and "Sakigake" into orbit. These were used in early 1986 within the framework of the International Program for the Study of Halley's Comet. However, the capacity of these solid fuel BR is insufficient to place an AES of applied economic significance into geostationary orbit, primarily a communications satellite, which Japan, being an island country, needs so greatly. This would require liquid fuel BR, and Japan has not had /59 experience in developing these.

At first Japan began using the American "Delta" booster rockets for launching its satellites into geostationary orbit. These were launched generally from the Japanese cosmodrome. Individual stages of these BR, which came to be called "En-1" and "En-2" in Japan, were purchased in the USA or made in Japan with American license, sometimes with the participation of American companies. The latter allowed the Japanese to gain a certain experience in the sphere of development of liquid BR. Particular significance is being given to this fact, since Japan is striving to end its dependence on the USA in the field of rocket-space technology. Such a dependence, aside from all else, deprives Japan of the possibility of gaining a profit from presenting its BR to other countries on a commercial basis. According to the conditions of the agreement with the USA, this is not permitted if even a single element of the BR is "American in origin". Thus, the USA is artificially limiting the capacities of its potential competitor.

The BR "Eich-1" which was used in the launches of 13 August 1986 and 27 August 1987, is the most important factor in the matter of freeing Japan from American dependence.Whilethe first liquid-fuel stage of this BR and the solid-fuel accelerators are of American origin, the second liquid-fuel stage is entirely made in Japan. The solid fuel third stage is also of Japanese production. The launch weight of the three-stage BR "Eich-1" is 140 tons, and its length is 45m. It can place a payload of 550 kg into geostationary orbit. For comparison we will point out that for the BR "En-1" this value comprised 130 kg, and for the BR "En-2" it was 350 kg.

The development of a second stage of the "Eich-1" booster rocket, equipped with liquid fuel rocket engines (LRE) LE-5 operating on liquid hydrogen and liquid oxygen, is a significant achievement of Japanese scientists and engineers. It is enough to say that the USA (for the BR"Delta-2") and India (for its prospective GSLV booster rocket) conducted negotiations for obtaining this stage. The development of a hydrogen-oxygen rocket is quite complex. This is evidenced, for example, by the experience of operation of the West European BR "Arian", which has had several accidents due to problems with the third hydrogen-oxygen stage. After the last accident, which occurred in May of 1986, the "Arian" /60
booster rocket was not used for over a year.

The thrust of the LRE LE-5 is 103 kN, i.e., greater than the LRE of the hydrogen-oxygen stage of the "Arian" booster rocket (61 kN), and significantly greater than the LRE of the hydrogen-oxygen stage of the Chinese booster rocket "Great Approach-3" (about 50 kN). With the seventh prototype of the "Eich-1" booster rocket the thrust of the LRE LE-5 will be increased to 120 kN. The launch of this sample BR is planned for 1990. Despite the comparatively low pressure in the combustion chamber (38 kg/cm^2) of the LRE LE-5, it has a rather high specific impulse for an engine of this type--445-449 units. It is intended for two ignitions, i.e., one stage performs the function of two stages. The overall duration of operation of the LRE is 355 sec.

The guidance system of the "Eich-1" BR is also made in Japan, while the BR "En-1" and "En-2" used American guidance systems.

The next step, which will finally give Japan its independence from the USA in the field of booster rockets is the creation of the "Eich-2" booster rocket, whose development is already underway. The first experimental launch of this BR is planned for the mid-90's. It will be able to place a payload of up to 2 tons into geostationary orbit. That is the approximate weight of the heavy communications satellites which Japan needs. This BR has two stages. Both stages are equipped with hydrogen-oxygen LRE: on the first is the LE-7, on the second is the already familiar LE-5. The booster rocket uses two solid fuel accelerators. The launch weight of the BR is 225 tons, its length is 48 m, and its diameter (without accelerators) is 4m. The LRE LE-7 has a thrust of 911 kN at sea level and 1200 kN in a vacuum. The specific impulse is 449 units. The duration of operation is 315 seconds. The second stage of the "Eich-2" booster rocket represents a scaled-up second stage of the "Eich-1" BR and correspondingly carries a significantly larger fuel reserve. Thanks to this, the LRE LE-5 at the second stage of the "Eich-2" BR can operate not for 355 seconds, as on the second stage of the "Eich-1" BR, but rather for 1430-1650 seconds. The solid fuel accelerators made by the Japanese company Nissan for the "Eich-2" BR are also significantly more powerful than the accelerators made by the American firm "Thiokol" on the "Eich-1" BR. The accelerators on the "Eich-2" BR have a length of 23m, a diameter of 1.8m, and a fuel charge weight of 59 tons. The thrust of each one at sea level is 1600 kN, and the duration of operation is 95 seconds. In the inertial system of guidance the BR, three circular laser /61
gyroscopes are used. This is an original Japanese development.

The necessary expenditures for the development of the BR "Eich-2" are estimated at about 1 billion dollars (independence is not cheap!). Of this sum, 25% is earmarked for the development of the LRE LE-7--the most complex element of the BR. The expenditures for the launch of one BR reach approximately 60-70 million dollars, so its operation will be an expensive proposition both for Japan and for the future commercial users from other countries.

In the next 10 years, the development of the "Eich-2" BR will be the main element of the Japanese space program. In second place is the multi-purpose space laboratory, which is to be a part of the American orbital station. This laboratory will be placed in orbit by the American multi-use transport ship (MUTC) "Space Shuttle", which will also subsequently deliver cargo to the laboratory. However, the possibility of using the space shuttle for delivering cargo is problematic. A very large number of shuttle flights may be needed for performing the military programs of the USA. The BR "Eich-2" is viewed as a reserve means for delivering cargo on board the Japanese space laboratory. Under conditions of a shortage of American booster rockets, the Japanese BR "Eich-2" may turn out to be useful also for other operations associated with the operation of the American orbital station. Thus, while at one time Japan resorted to the use of American BR, in the future the situation may be reversed.

The long-range Japanese program provides for the development of an orbital station soon after the year 2000. The cargo will be brought to the station by a multi-use unmanned ship launched with the aid of the "Eich-2" BR, i.e., this BR is viewed as the universal means for placing payloads into space, a means which Japan will be able to use without having to worry about any limitations imposed on the part of the USA.

These are the ambitious plans of this country for the long-term future. However, the longest journey begins with the very first steps. Such steps were the first launches (of the "Eich-1" rocket on 13 August 1986 and 20 August 1987).

CHRONICLE OF COSMONAUTICS*

5 AUGUST in the People's Republic of China the 20th Chinese AES was launched from Shuan Chen Tse cosmodrome with the aid of the "Great Approach-2" BR. It entered orbit with a perigee of around 175 km, an apogee height of around 415 km, and incline of 63°. Its period of rotation was about 90 minutes. After 5 days the AES was returned to Earth. According to the official reports of the PRC, experiments were conducted on board the AES in the field of space technology in accordance with the PRC program, as well as two experiments (in the field of space technology and space biology) in accordance with the program of the French company "Matra". This is already the 9th Chinese AES which has returned to Earth.

18 AUGUST--the USSR launched its regular (17th) operational meteorological AES "Meteor-2". Placed in circular polar orbits, these AES provide global images of cloud cover and underlying surface in the visible and infrared rances, as well as observation of the flow of penetrating radiation in the space around earth. The apparatus of the "Meteor-2" satellite may operate in a memory regime as well as in a mode of direct transmission of information, which is forwarded to the State Scientific-Research Center for the Study of Natural Resources and to the USSR Hydrometeorological Center.

27 AUGUST--Japan launched the AES "Kiku-5" from its cosmodrome in Tangasima to a geostationary orbit at a point of "hovering" over 130° e. lon. It was intended for experiments for navigational provision of transport means (primarily airplanes on transoceanic flights). The "Eich-1" Japanese BR in a three-stage variant was used for the first time to launch this satellite. Previously (18 August 1986), the first launch of this BR was performed, but in a two-stage

---

*CONTINUATION (cf. No 8 for 1987). Based on the materials of various information agencies, data are presented on the launches of certain artificial Earth satellites (AES). The information on manned flights is given in other appendices. The launches of the satellites of the "Kosmos" series, for example, are regularly announced on the pages of the journal PRIRODA, to which we refer interested readers.

variant. This AES became the first Japanese communications satellite developed by that country's own industry. (For the first time a tri-axial stabilization was used for a Japanese geostationary AES).

3 SEPTEMBER--the next (16th) AES for television broadcasting, "Ekran", was launched with the aid of the BR "Proton". Placed into geostationary orbit at a point of "hovering" at 99^{o} e. lon. (international registration index "Stationar T"), these satellites are used for broadcasting television programs in the decimeter wavelength range to regions of the Priural'ya (Urals region) and Siberia to subscriber's collective use receiving installations.

9 SEPTEMBER--the People's Republic of China launched the 21st Chinese AES from the cosmodrome at Tszyu Tsuan' (formerly Shuan Chen Tsi) with the aid of a "Great Approach-2" BR. It entered orbit with a perigee height of 204 km and apogee height of 313 km, and incline of 63^{o}. On 17 September its descent craft was returned to Earth, to the province of Szechuan.

16 SEPTEMBER--The Australian communications satellite "Aussat-3" and the West European communications satellite "Eutelsat-4" were launched from the Kuru cosmodrome with the aid of the West European BR "Arian-3" onto geostationary orbits. The computed point of "hovering" of the first AES was 164^{o} e. lon, and the second--10^{o} e. lon. The previous two "Aussat" satellites were launched in the American Space Shuttle. The "Eutelsat-3" satellite was not launched into orbit due to the accident of the "Arian" BR on 13 Septemper 1985 during its 15th launch. After an interruption of several months, the launches of these BR were renewed, and the 16th and 17th launches were successful. However, on the 18th launch on 30 May 1986 there was again an accident (again due to malfunction in the third stage). This time the break in operation of the "Arian" BR lasted over 15 months, and it was specifically in that period, when after the catastrophe of the Space Shuttle and the accidents of several American BR that the countries of the West practically lost the capacity for putting payloads into space with the aid of American booster rockets.

TABLE OF CONTENTS